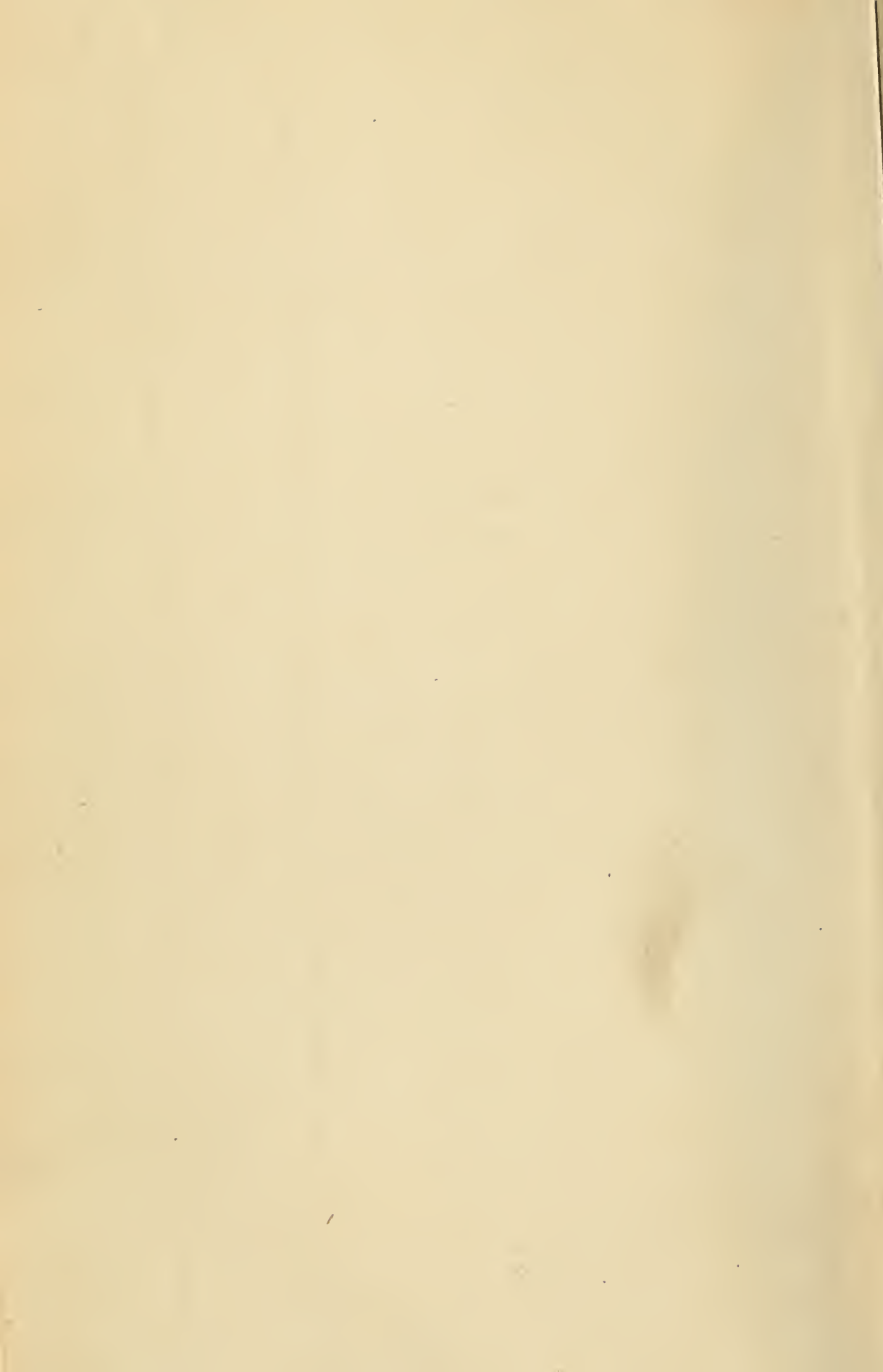




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111
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No. 1

RESISTIVITY OF COPPER IN TEMPERATURE
RANGE 20° C. TO 1450° C.*

BY
EDWIN F. NORTHRUP, Ph.D.,
Member of the Institute.

THE present paper is confined to a statement of the facts experimentally obtained respecting the resistivity of copper in the temperature range 20° C. to 1450° C., and to such description of the methods of measurement and apparatus employed as may be necessary to a clear understanding of the results here recorded. It is one report of the progress being made in the extended investigation undertaken by the writer¹ upon the electrical conduction of matter over extended temperature ranges.

I. SPECIAL DIFFICULTIES CONNECTED WITH MEASURING THE
RESISTIVITY OF MOLTEN COPPER.

The accurate measurement of the resistivity of molten copper presents peculiar difficulties, and the ready measurement of the resistivity of this metal was constantly kept in mind when devel-

* Communicated by the author.

¹ Mr. V. A. Suydam, who joined the writer in this research, was called to another university and gave up his connection with the research before the method and measurements recorded here were made. The writer wishes to express his indebtedness to Mr. Suydam for his contribution to this general research in its earlier stages.

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oping the general method for measuring the resistivity of any molten metal, alloy, or molten salt. The method is now practically perfected for measuring copper, and may be applied with but slight modifications to the accurate and rapid measurement of any other molten metal or alloy or molten salt which melts under a temperature of 1600°C . or higher. Modifications of the method used for copper have been very successfully employed which are less costly and simpler to use, but which are confined to temperatures under 1100°C . A description of these modifications must be left to a future report.

The chief difficulty in tracing experimentally the resistivity curve of copper to temperatures high above its melting-point is due to its strong affinity for oxygen. If the molten metal oxidizes at any exposed surface it immediately absorbs its own oxide and its resistivity may increase 10 per cent. or more. The metal must be protected, therefore, from oxidation before and while the measurement is being made. It is also contaminated with hydrogen gas, and this precludes the use of a molybdenum wound furnace the winding of which is protected in a hydrogen atmosphere. Molten copper is inert in a CO atmosphere, and arrangements were provided for making the measurements in this atmosphere.

Minor difficulties result from the high melting-point ($1082.6 \pm 0.8^{\circ}\text{C}$.) of copper, and from its extreme fluidity when molten. The container for the molten metal must be constructed in a particular fashion and with great care to prevent the copper leaking from minute and unobtrusive cracks.

It is impossible to be certain, because of the tendency to contamination, that any single measurement, however carefully made, is correct. The result can only be known to be accurate when independent measurements, made at different times and in different containers, agree. In the early stages of the work measurements of the resistivity were made at some hundred degrees above the melting-point in which the most extreme care was used to be accurate, but which later proved to be many per cent. too high because the copper became contaminated by absorbing its own oxide and by alloying with the terminals (nickel or iron) then used.

All sources of error from these causes have been avoided in

the measurements here recorded, and independent determinations check with satisfactory precision.

II. REQUIREMENTS IN THE METHOD AND APPARATUS FOR MEASURING THE RESISTIVITY OF COPPER TO 1500° C.

For measuring the resistivity of copper in the range 20° C. to 1500° C. or higher one must have:

(a) An accurate electrical method of measuring resistance in which local thermal electromotive forces will be without influence. The method should preferably be a null method and read the resistivity at each recorded temperature directly and without corrections, in microhms per centimetre cube.

(b) Means for accurately reading the temperature.

(c) A container which will hold molten copper without danger of leaking, and which is provided with holes suitably arranged for current and potential leads, a hole for filling and one for holding a thermocouple, or for sighting down with an optical pyrometer. A special contrivance must be devised by which the extent of the apparent increase in resistivity due to shrinkage when the metal solidifies may be estimated and allowed for.

(d) A provision for making connection with the ends of the columns of molten metal which form the current and potential terminals. This connection must be made in a manner not to abstract much heat or contaminate the copper or have a high or uncertain resistance.

(e) Means for completely protecting the metal from air or other contaminating influences.

(f) Means for calibrating the container and setting the ratio coils of the bridge used so that the readings are given without requiring correction and directly in microhms per centimetre cube.

(g) Lastly, a tubular electrical furnace is required which will give, say, a temperature of 1600° C. without being strained, and a very uniform temperature over a considerable length of its tube. The temperature must be under perfect control and the furnace should not be injured with the vapors of any kind of metal. In the case of copper this furnace must operate with a CO atmosphere in its tube.

These various requirements and arrangements have all been

met and provided, and I shall briefly describe at this time all but the electrical furnace. This last piece of apparatus was specially developed for the research and has proved to be very satisfactory. It will be described in a later report, and it is planned to place it upon the market so it may be available to others.

The method, container, and furnace would have permitted the temperature to have been raised to at least 1800°C. , but it was thought the thermocouple, then available, would be injured or have its calibration altered if the temperature was pushed higher than that used in the measurements. In fact, with the temperature used, as is later explained, the calibration was changed by some 10°C. in the second and third measurements.

III. METHOD AND APPARATUS.

The electrical method adopted for measuring the resistivity was the Kelvin-double-bridge method. Fixed ratio coils and a variable standard were employed. The variable standard used is one having a range, with even ratios, of 0 to 0.01 ohm. This piece of apparatus was in large part designed by the writer when with the Leeds & Northrup Company, and is sold by this company under the name "Variable Standard Low Resistance," Catalogue No. 4300. It is described in Pamphlet No. 40. The ratio coils which attach to the variable standard were called α and α and were set at a fixed even value. The ratio coils which attach to the unknown resistance were called b and β and were also set at a fixed value. Their value was so chosen by a rule to be described that the readings on the variable standard, when multiplied by 10^4 , were directly in microhms per centimetre cube. The b and β values were obtained from an Otto Wolff box of ratio coils for use in Kelvin-double-bridge measurements. The box is listed in Otto Wolff's catalogue, paragraph 53.

In all cases, before a measurement was made of the resistivity of the sample, the current and potential leads from the measuring apparatus were attached to a standard 0.001 ohm made by Otto Wolff. If the apparatus measured this correctly (as it always did), assurance was given that the measuring part of the outfit was in proper working order and that no electrical leakage, bad contacts, etc., were present in a way to produce a hidden and constant error.

The galvanometer used with the Kelvin double bridge was a Leeds & Northrup high sensibility, narrow-coil galvanometer, Catalogue No. 2290. Its period is about $2\frac{1}{2}$ seconds. Its sensibility, coil resistance, etc., were especially selected to be most suitable for the work in hand. The deflections were read with a lamp and scale.

Measurement of Temperature.

The temperatures were measured with a platinum *vs.* platinum + 10 per cent. rhodium thermocouple protected in a clear quartz tube. This couple was sent to the Bureau of Standards and a certificate obtained. A couple of this kind will not stand many heatings to 1400° C. or 1500° C. without changing its calibration.

The thermocouple-electromotive forces were read with a Leeds & Northrup potentiometer, Catalogue No. 7551, in conjunction with a specially-selected galvanometer of the same type as the one used with the Kelvin double bridge.

The cold junction of the thermocouple was kept at 0° C. by immersion in ice water contained in a Dewar flask. In this work, if the thermocouple changes its calibration, the fact, and the extent of the change at one temperature, becomes known. The solidification temperature of the metal is accurately known, and when solidification starts the resistance changes suddenly. At this moment the thermocouple should read the temperature of freezing of the metal, and by the amount it fails to do so has its calibration gone off.

The Container.

The construction of a container which would permit the measurement of the resistivity of any metal when in the molten state (excluding metals like tungsten and molybdenum, which melt at a temperature exceeding 2000° C.) proved to be an exceedingly difficult matter. The container, which is here described and which perfectly meets all requirements, was not arrived at without very many trials and rejections of unsuitable forms. Some of the conditions which had to be met are:

The selection of a material which will not melt or soften under a temperature of 2000° C.

A material which at the highest temperature employed has a

resistance far in excess of the resistance of the metallic circuit being measured.

A material which will not expand or shrink by an appreciable amount nor develop, on heating or cooling, the minutest crack.

The container must not give off at any temperature the slightest trace of gas.

It must be chemically inert in respect to any molten metal to avoid all contamination.

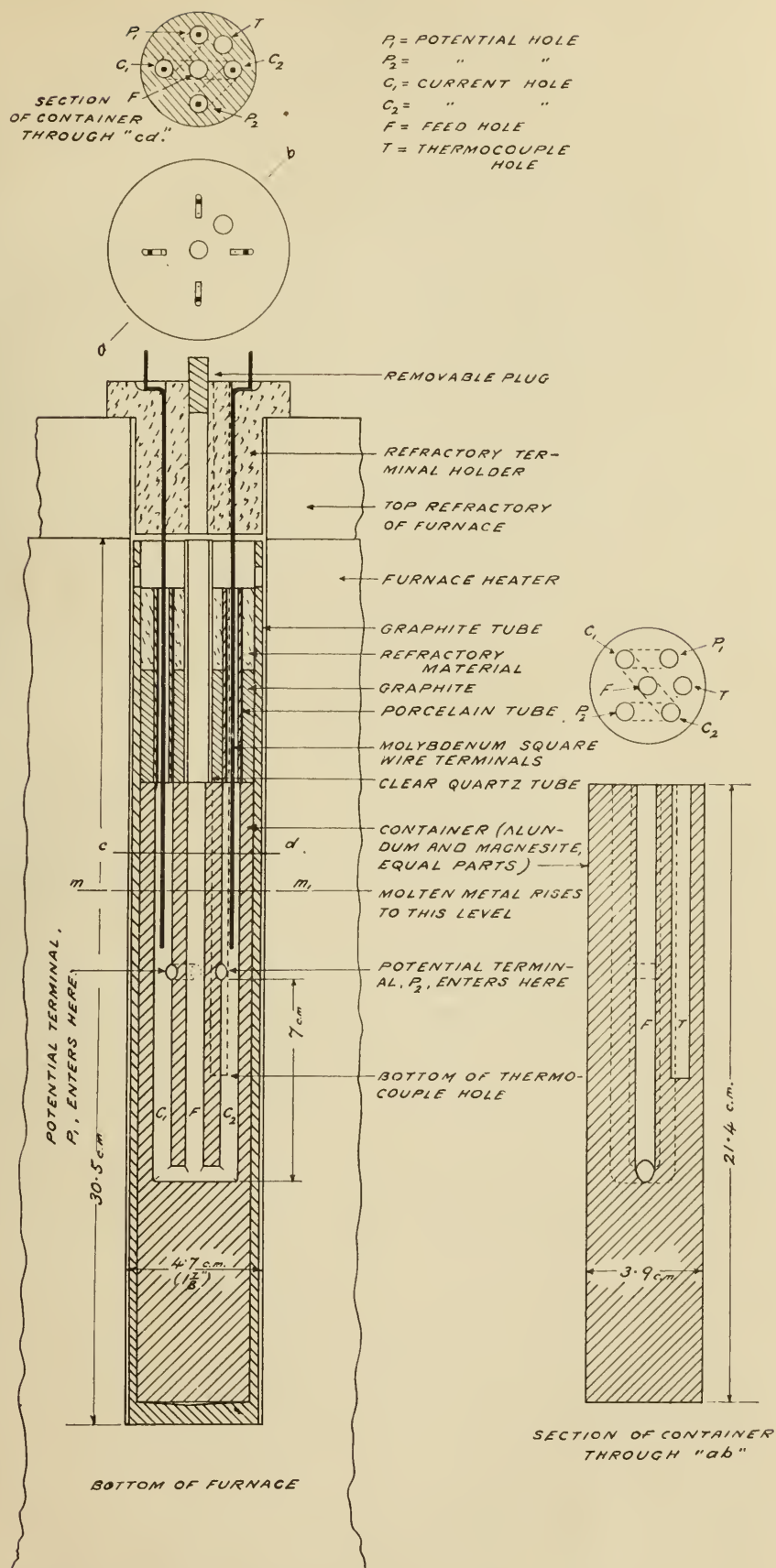
Lastly, this material must be in powdered form so it may be moulded and packed into any shape and drilled while soft. It must then, upon high heating (to 1400° C. or 1500° C.), become mechanically strong and very hard. Repeated heatings and coolings must produce no further change or modify its shape.

All compositions containing silica were rejected because silica interacts with certain metals (especially aluminum). All compositions containing carborundum, also porcelain, were rejected because when hot the resistance is low.

I have used pure alundum cement, grade RA 355, but this is prone to develop cracks and shrinks on a first heating. Pure magnesite was tried, but this is rather coarse-grained and difficult to make sufficiently coherent for drilling, etc., before firing. Successful containers may, however, be constructed out of either of these materials. But the best results were had when the containers were made of magnesite cement, finest ground, 50 parts by weight, and alundum cement, grade RA 355, 50 parts by weight. These two materials are sold by the Norton Company, Worcester, Mass. The magnesite and alundum are very thoroughly mixed together as dry powders. A very little water is then added and the mass again thoroughly mixed. This composition is then packed and pounded very hard in an iron cylinder, which separates longitudinally into two halves. The inner wall of the cylinder is lined before packing with bristol board, well oiled. This arrangement permits easy removal of the cylinder after packing and drying out in a gas oven.

It was early decided that the diameter of the columns of molten metal which was being measured should be as great as 6 or 7 millimetres, and this, together with a 7-millimetre hole for insertion of the thermocouple, determined the diameter of the cylinder of refractory material. Fig. 1 shows, with all dimen-

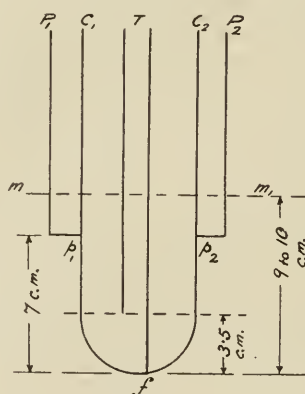
FIG. 1.



sions given, not only the completed container, but also the graphite tube with the bottom end closed into which the container fits, and the arrangement of the top cap of graphite and refractory material employed, and the furnace-tube cover with the terminals in place.

The six vertical holes are drilled with a $\frac{1}{4}$ -inch wood bit before the container is removed from its mould. The container is then dried out in a gas oven and removed from its mould. The cross holes are then located and drilled. Rods of metal which fit the holes are then inserted in them. The three side holes which make an exit to the outside of the cylinder are then packed with *the same* composition as the container is made of. The rods are

FIG. 2.



removed and the container is placed in the graphite tube, lowered into the furnace, and fired for several hours at a temperature of not less than 1400° C. When removed it is strong and very hard, has no cracks and is ready for use, and possesses all the requisite qualities above enumerated.

Referring to the skeleton diagram, Fig. 2, C_1 and C_2 are holes for the insertion of the current terminals, P_1 and P_2 for insertion of the potential terminals, F a hole for feeding in the metal (in the form of about No. 12 wire) to be measured, and T the hole for insertion of the thermocouple. When the container is filled the molten metal rises to about the height indicated by the dotted line mm_1 . The resistance path of the metal measured is the path p_1fp_2 . It will be noted that the end of the thermocouple

reaches to the mid point from where the potential holes tap off and the bottom of the metal columns. The axial distance of the thermocouple from the axis of the container is the same as the axial distance of the metal columns. Thus the thermocouple records quite precisely the mean temperature of the metal circuit $p_1 p_2$.

The Terminals.

The writer found by trial that molybdenum wire (about 2 mm. diameter square wire was used) is a most satisfactory material to use for terminals to make connection with the tops of the columns of molten metal. This wire will not alloy at high temperatures in gold, mercury, bismuth, tin, lead, zinc, cadmium, antimony, aluminum (only slightly and at a high temperature), or copper, and this is presumably the case for all metals outside the group iron, nickel and cobalt. The terminals used in measuring copper were of this material, and after several hours' immersion in molten copper at over 1400° C. the sharp edges of the square wire were not eaten or dulled in the least.

Prevention of Oxidation.

Copper is unaffected in a CO atmosphere. Hence by placing the container in a graphite tube with a graphite piece over the top (which further aids in maintaining the entire container at a uniform temperature), and then using a furnace which develops in its interior only a CO atmosphere, the copper is kept entirely away from oxygen. When prepared for feeding into the container, the wire used is cut into short lengths, about 15 centimetres, and dropped into the feed hole of the container through a small hole in the furnace cover piece. The small hole is immediately plugged, and thus no air can possibly reach the copper. In this way copper is fed into the container until a circuit is established through the current leads attached to the Kelvin bridge.

Calibration of the Container.

The container is calibrated so that the readings may be obtained directly in resistivity, microhms per centimetre cube, as follows:

For this purpose the container is filled with pure mercury and the resistance is measured at a known temperature.

Let R_t = the resistance of the container filled with mercury and ρ_t = the known specific resistance of mercury. Then

$$R_t = K\rho_t \dots\dots\dots (1)$$

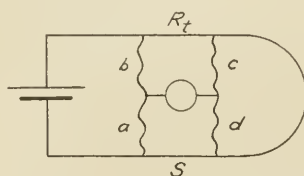
where K is the constant of the container. Then if R'_{t_1} is the resistance of the container when filled with the metal under test at a temperature t_1 , we have

$$R'_{t_1} = K\rho'_{t_1} \dots\dots\dots (2)$$

where ρ'_{t_1} is the required resistivity at temperature t_1 of the metal under measurement. From Equations (1) and (2)

$$\rho'_{t_1} = \frac{R'_{t_1}}{R_t} \rho_t \dots\dots\dots (3)$$

FIG. 3.



By the law of the Kelvin double bridge

$$R'_{t_1} = \frac{b}{a} S \dots\dots\dots (4)$$

where b and a are the values of the ratio coils (see Fig. 3), and S is the setting of the variable standard which gives a balance. Putting this value of R'_{t_1} in Equation (3) gives

$$\rho'_{t_1} = \frac{b\rho_t}{aR_t} S \dots\dots\dots (5)$$

The scale of S is laid off in ohms and its maximum reading is 10^{-2} ohms. It is evident that if $\frac{b\rho_t}{aR_t} = 1$ the readings of S will give the resistivities directly in ohms. If the readings of S are multiplied by 10^6 , then ρ'_{t_1} is given in microhms. Hence to have

the bridge read in microhms we must place $\frac{b\rho_t}{aR_t} 10^6 = 1$. If, because of the limit of the variable standard, we again multiply its readings by 10^4 we should then place

$$\frac{b\rho_t}{aR_t} 10^6 \times 10^{-4} = 1.$$

This gives

$$b = \frac{R_t}{\rho_t} a 10^{-2} \text{ ohms} \dots\dots\dots (6)$$

as the proper setting for the ratio coil b (and the ratio coil β). If when b has this value a balance is obtained when the variable standard reads, for example, 0.001734, the resistivity is 17.34 microhms per centimetre cube. The value of a is arbitrarily selected, the resistance R_t of the mercury in the container is measured at the temperature t , and the resistivity of pure mercury at the temperature t is known.

In the measurement of copper made October 29, 1913, the values found and used for obtaining the value of b were:

$a = 1000$ ohms, by selection.

$R_t = 7736.2 \times 10^{-6}$ ohm = resistance of mercury in container when at a temperature of 23° C.

$\rho_t = 96.074 \times 10^{-6}$ ohm = the resistivity of mercury at 23° C.

(The values of the resistivity of mercury used are those of Kreichgauer and Jaeger, and the mercury used was some which was furnished me by Prof. G. A. Hulett. It had been three times distilled in vacuum.)

These values placed in Equation (6) give $b = 805.23$.

The Furnace.

The furnace employed was especially developed for this research. It is of the tubular type with heating tube 30 centimetres long and stands with the tube vertical. The length of tube which heats uniformly is about twenty centimetres. The internal diameter is 4.762 centimetres. The furnace will melt platinum without being destroyed. It automatically develops in its tubular space

an atmosphere of pure CO. This furnace serves for measuring the resistivities of all substances which melt under 1700° C. or possibly 1800° C.

IV. PROCEDURE FOLLOWED IN MEASURING COPPER.

In planning this measurement it was hoped that a precision might be obtained in which the greatest departure from the mean

FIG. 4.



Furnace and accessories.

of different determinations of the resistivity of copper in the molten state would not exceed 0.25 of one per cent. The results, as will appear later, show that a precision better than this has probably been obtained.

In making a measurement the ordinary course of procedure

is to bring the container to a high temperature, above the melting-point of the metal, fill the container and take readings of resistivity and temperature while the furnace very slowly cools. So long as the metal is in the molten state the actual values as well as the relative values at different temperatures of the resistivities will be correctly measured. When, however, solidification occurs the cross section, but not the length, of the metal which lies between the potential points will diminish, due to the contraction of the metal which occurs when it passes from the liquid to the solid state. If the resistivity of the metal has been determined previously at 20° it will always be found (in the case of metals which contract upon solidification) that when this temperature is reached the measured resistivity is several per cent. too high. The rate of change of the resistivity with temperature after solidification occurs is given correctly, however. If, therefore, we are to trace the true resistivity curve through the solid into the liquid state we must draw a curve through the point which gives the resistivity at 20° C. and below the resistivity curve obtained upon cooling after the metal has solidified. In the determination of the resistivity curve of copper an independent determination was made, as an extra precaution, of the increase in resistivity with temperature as the temperature was raised from 20° C. to a point where the metal between potential points was all melted. This was accomplished by making a metal form of No. 3 B. and S. copper rod which had approximately the same size and shape as the channels in the container which form the current and potential holes (see also Fig. 2). The arrangement constituted a rod of copper bent into the form of a hairpin with two other rods, serving for potential terminals, attached to it at about 8 centimetres from the lower rounded end. This copper-form was imbedded in a cylinder of alundum cement packed very hard. A suitable hole was drilled for the insertion of a thermocouple. The cylinder was 30 centimetres long and 5.72 centimetres in diameter. This was wound from one end to the other with a strip of molybdenum about 0.8 centimetre wide and 0.2 centimetre thick. The cylinder so wound was placed in a vessel and packed with a refractory heat-insulating material. The temperature was then very slowly raised by passing current through the molybdenum winding, and the resistance

and temperature were measured at frequent intervals. As might be expected when the metal melted, the expansion opened longitudinal cracks in the cylinder and the molten metal ran out and brought the measurements to an end. This did not occur, however, until the curve had been traced from 20° to 1143° C. The resistivity of the sample of copper was also very carefully determined at 20° C., and thus data were obtained for tracing the resistivity curve from room temperature to a temperature where the metal between potential points was all molten (see Curve I).

Since the per cent. conductivity of copper is the best index of the chemical purity, no chemical or other tests were made of the purity of the copper used. The copper used in the measurement of the resistivity in the solid state, just described, was selected from one lot and the copper used in the two independent determinations, where the resistivities were traced from the molten state to 20° C., was taken from another lot. The conductivity by Matthiessen's meter millimetre standard was, for the copper used in the first determination, 99.71 per cent., and for the copper used in the second and third determinations, 99.39 per cent.

V. TABLES, DATA AND CURVES.

Some of the data obtained are more accurate than can be represented in curves which it is practicable to reproduce in a printed article. For this reason and because of the additional information given I shall now give tables which present the data as they were obtained in three determination.

The data recorded in Tables I, II, and III are plotted in the curves. Curve I is a plot of the resistivities ρ'_t in range 20° C. to 1143° C. obtained from copper in the solid state with rising temperature, Curve II belongs to the second determination, the resistivities being measured with falling temperature from 1394° C. to 20.5° C., and Curve III belongs to the third determination, the resistivities being measured with falling temperature from a recorded temperature of 1443° C. to 22.3° C.

VI. INTERPRETATION OF RESULTS.

Examination shows that below a temperature of 1143° C. the three curves do not coincide. This lack of coincidence is explainable and is not prejudicial to the accuracy of the results.

TABLE I.

Determination of Resistivity of Copper in Range 20° C. to 1143° C.

Date, March 20, 1913.

Observers: E. F. Northrup, Mrs. E. F. Northrup, V. A. Suydam.

NOTE.—The sample was a No. 3 B. and S. soft copper rod bent into the form of a hairpin, and the resistance was measured between potential points with a Kelvin double bridge. The temperatures were measured with the certified platinum *vs.* platinum + 10 per cent. rhodium thermocouple. All measurements were made with rising temperature. An independent determination gave the resistivity of the copper used in this measurement as 1.7290 microhms at 20° C. As the resistivity of the copper used in the second and third measurements was 1.7347 microhms at 20° C., all values of resistivity ρ'_t obtained in this measurement have been multiplied, for purposes of comparison, by $\frac{1.7347}{1.7290} = 1003$ and called ρ'_c .

Degrees C. <i>t</i>	Resistance in microhms	Resistiv- ity ρ_t in microhms	Resistiv- ity ρ'_c in microhms	Remarks
24.0	136.7	1.757	1.761	Began 3:05 P.M.
71.4	161.4	2.075	2.081	
117.9	186.1	2.392	2.397	Ratio $\frac{b}{a} = \frac{400}{10,000}$
148.0	208.4	2.678	2.686	Time 3:40 P.M.
238.0	253.7	3.261	3.270	
298.0	285.1	3.665	3.676	
353.0	315.3	4.053	4.065	
435.0	358.6	4.609	4.622	
495.0	391.2	5.029	5.044	
543.0	420.5	5.406	5.422	
647.0	482.0	6.195	6.213	Ratio $\frac{b}{a} = \frac{800}{10,000}$
763.0	558.5	7.179	7.200	
881.0	639.0	8.213	8.237	Time 7:50 P.M.
945.0	688.0	8.843	8.870	Time 8:05 P.M.
1001.0	733.0	9.421	9.448	Ratio $\frac{b}{a} = \frac{900}{1800}$
1041.0	774.0	9.948	9.978	Time 8:50 P.M.
1066.0	813.0	10.450	10.480	
1082.0	914.0	12.020	12.090	
1088.0	1025.0	13.170	13.210	
1093.0	1150.0	14.780	14.820	
1097.0	1250.0	16.060	16.110	
1100.0	1350.0	17.350	17.400	
1103.0	1500.0	19.280	19.340	Time 9:15 P.M.
1117.0	1650.0	21.210	21.270	
1143.0	1697.5	21.820	21.880	

TABLE II.

Determination of Resistivity of Copper in Range 1394° C. to 20.5° C.

Date, October 10, 1913.

Observers: E. F. Northrup, Mrs. E. F. Northrup.

NOTE.—By an independent determination the resistivity of the copper used in this measurement was found to be 1.7347 microhms at 20° C. Copper of 100 per cent. conductivity has a resistivity at 20° C. of 1.7241 microhms (Bulletin No. 31 of Bureau of Standards, p. 9). Hence the conductivity of copper used in test is $\frac{1.7241}{1.7347} 100 = 99.39$ per cent.

Only measurements made with falling temperature are here recorded. Container No. III used.

Thermo- couple e. m. f. in microvolts	Tempera- ture in de- grees C.	Resistiv- ity in mi- crohms	Time	Remarks
13,464	1394	23.78	4:11 P.M.	Measuring current 10 ampères, $b = 635.4$ ohms, $a = 1000$ ohms.
12,830	1340	23.39		
12,422	1307	23.12		
11,693	1244	22.61	4:20 P.M.	Resistance of container filled with mercury = 6102 microhms at 22.7°C. $\rho_{22.7} = 96.045$ microhms.
10,974	1182	22.11		
10,250	1120	21.61		
9,869	1087	21.31		
9,800	1082	20.57		
9,731	1076	19.10		
9,684	1072	17.59		
9,650	1067	16.58		
9,624	1065	15.58		
9,596	1064	14.57		
9,512	1056	11.56		
9,440	1050	10.35		
9,190	1027	10.05	4:44 P.M.	Set $b = 635.4$, $a = 10,000$.
8,940	1005	9.85		
8,829	993	9.748	4:49 P.M.	
8,590	978	9.547	4:52 P.M.	
7,998	920	9.045		
2,591	364	4.572		
2,570	361	4.531	10:05 P.M.	10/11/'13. Temperature taken with mercury thermometer. Read 11/14/'13.
	55.5	2.382	2:00 P.M.	
	20.5	2.133		

TABLE III.

Determination of Resistivity of Copper in Range 1443° C. to 20° C.

Date, October 29, 1913.

Observers: E. F. Northrup, Mrs. E. F. Northrup.

NOTE.—Copper from same lot as used in the measurement made October 10, 1913. Container No. V used.

Only measurements made with falling temperature are here recorded.
True resistivity at 20° C. = 1.7347 microhms.

Thermo- couple e. m. f. in microvolts	Tempera- ture in de- grees C.	Resistiv- ity in mi- crohms	Time	Remarks
14,042	1443	24.17	11:25 A.M.	Resistance of container filled with mer- cury = 7736.2 microhms at 23°C. $\rho_{23} = 96.074$. Set $b = 805.2$ ohms, $a = 1000$ ohms.
14,023	1441	24.16		
13,711	1415	24.00		
12,912	1347	23.50	11:39 A.M.	
12,175	1285	23.00		
11,450	1223	22.50	11:53 A.M.	
10,698	1158	22.00	12 M.	
9,963	1096	21.50		
9,795	1081	21.40		
9,765	1078	21.30		
9,746	1077	21.10		
9,702	1073	20.50	12:17 P.M.	
9,674	1070	20.00		
9,644	1067	19.50		
9,622	1065	19.00		
9,600	1064	18.50		
9,580	1063	18.00	12:19 P.M.	
9,560	1060	17.50		
9,540	1058	17.00		
9,523	1056	16.50		
9,504	1055	16.00		
9,490	1054	15.50		
9,473	1052	15.00		
9,455	1051	14.50		
9,438	1050	14.00		
9,420	1047	13.50		
9,400	1046	13.00		
9,385	1045	12.50		
9,364	1043	12.00		
9,328	1040	11.00		
9,300	1038	10.50		
9,258	1034	10.32	12:26 P.M.	
9,200	1028	10.24		
8,950	1007	10.00		Made $a = 10,000$.
8,870	998	9.942		
8,715	985	9.800		
8,180	937	9.330		
7,792	900	9.000	12:55 P.M.	
6,605	786	8.000		
4,192	540	6.020	3:35 P.M.	
4,151	525	5.987		
3,262	440	5.254	5:02 P.M.	
1,490	229	3.716	9:38 P.M.	
	223	2.243	8:50 A.M.	Reading made 10/30/'13. Tempera- ture by mercury thermometer.

Curves II and III begin to separate at the solidification temperature because the thermocouple which was used in obtaining the data for Curve II had had its calibration changed by being heated to the high temperature reached in this and the third measurements. This is proved by the fact that at the moment the copper started to solidify in the third measurement the registered temperature was about 1072° when it was 1082.6° . The thermocouple was accidentally destroyed during the close of the measurement, or this statement would have been further verified.

If all the high temperatures of Curve III are moved 10° to the right the coincidence of Curves II and III becomes practically perfect. With this understood, the two determinations, made at different times and in different containers having different constants, very closely check each other. Curve I necessarily, by the method of measurement used, lies below Curves II and III when the copper is in the solid state. That it does not exactly parallel this curve from temperature 20° C. to 1000° C. may perhaps be explained in part by the fact that the conductivity of the copper used for getting Curve I was 99.71 per cent., as against 99.39 per cent. for the copper used in getting Curves II and III, and consequently had a different coefficient. Possibly, also, expansion of the copper in the one case and contraction in the other cases have an important effect on the slope of the curves, and the loss of heat by conduction toward the terminal attachments may have introduced some uncertainty into the data of Table I at the higher temperatures.

It will be noted that with rising temperature the curve begins to bend upward decidedly at the melting temperature of copper, but the resistivity is not that of molten copper until a temperature of about 1143° C. is reached. On the other hand, with the falling temperature employed in obtaining Curves II and III the resistivity abruptly diminishes very closely to the solidification temperature of copper, but the resistivity of solid copper is not reached until the temperature has lowered (in the case of Curve II) to 1050° C. These features in the curves are to be explained by the fact that, so far at least, it has been found impossible to make the temperature perfectly uniform over the entire length of metal between potential points. Melting or solidification does not, therefore, take place at the same instant over the entire length of metal being measured. If such occurred the change in resistance in passing from solid to liquid or from liquid to

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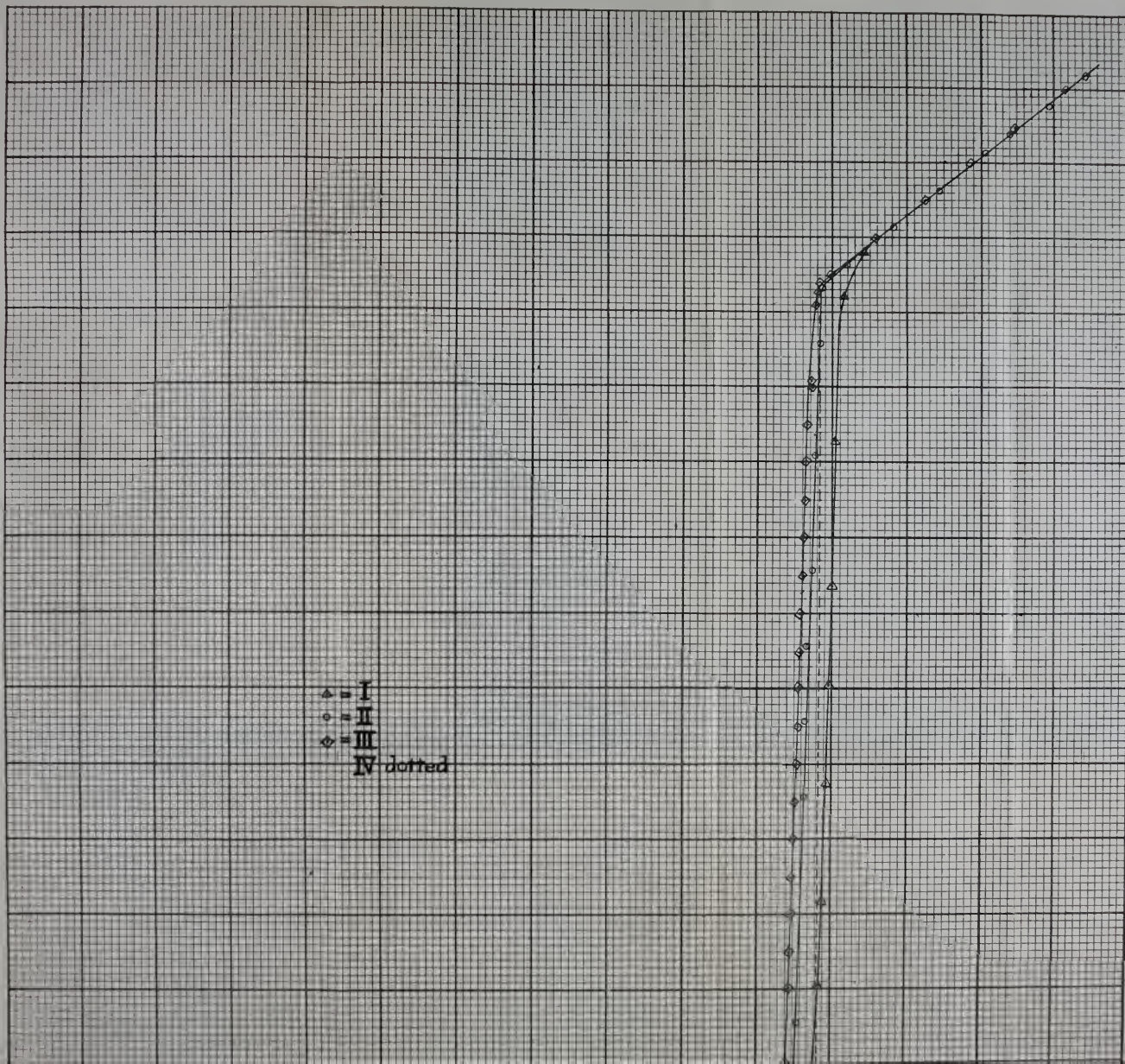
14

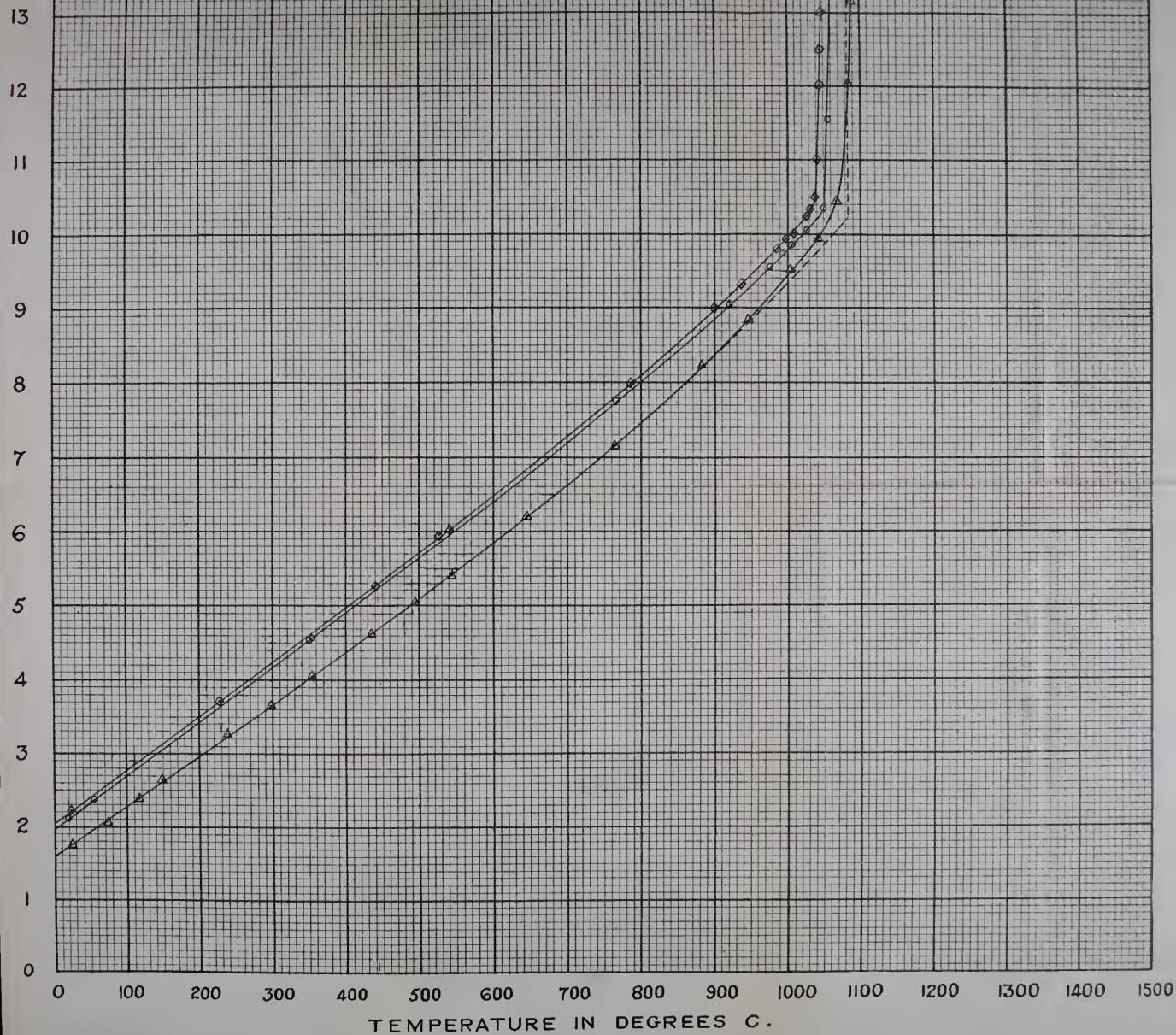
13

12

RESISTIVITY IN MICHRHMS

△ = I
○ = II
◇ = III
IV dotted





solid would be abrupt and would be represented by a perpendicular line, as shown in Curve IV. This curve has been drawn to represent, according to the writer's judgment, what is probably the true resistivity curve for copper from 20° C. to 1450° C.

It is difficult to assign the probable precision to the results shown by Curve IV, but the writer believes he is conservative in stating that in the liquid state the error does not exceed $\frac{1}{4}$ or at the most $\frac{1}{2}$ per cent.

Should any one repeat these measurements it must be borne in mind that the least oxidation of the copper introduces a contamination which may greatly raise the resistivity in the molten state. In an early attempt to measure copper, iron wires being used for terminals and the copper being exposed to oxidation, the resistivity obtained at 1241° C. was 36.2 microhms, whereas my present value is 22.60 microhms. Another determination was made in which there was no recognizable cause for contamination other than such oxide as formed at the top surfaces of the liquid columns. At 1432° C. the resistivity found was 27.6 microhms, whereas my present value at this temperature is 24.10 microhms. Thus it is concluded that the oxidation raised the resistivity about 14.5 per cent.

Using data taken from Curve IV we can find the ratio of the resistivity just after fusion to the resistivity just before fusion. Taking the former at 21.3 and the latter at 10.2, this ratio becomes 2.08₈.

These measurements suggest the possibility of determining the shrinkage which takes place when the metal solidifies, also when it further cools. If this is possible the calculation would be made as follows: Let it be assumed that the length of the channel in the refractory container from potential point to potential point remains constant and that such contraction as takes place in the metal measured is in cross section only. Let it be further assumed that the contraction in section is uniform from one potential point to the other. Then

Let S_s = cross section of metal when it fills the channel and S_c = cross section of metal when contracted.

Let R_s = resistance of metal when its cross section is S_s and R_c = resistance of metal when its cross section is S_c .

Then $\frac{S_s - S_c}{S_s}$ is the proportionate part of the original cross section by which the metal has contracted. It is the shrinkage.

If ρ_t is the true resistivity of a metal at a temperature t , then

$$R_s \propto \frac{1}{S_s} \rho_t \text{ and } R_c \propto \frac{1}{S_c} \rho_t$$

where 1 is the length of the channel. Thus

$$S_s \propto \frac{1}{R_s} \text{ and } S_c \propto \frac{1}{R_c},$$

and hence, calling C_t the contraction in section at temperature t , we have

$$C_t = \frac{S_s - S_c}{S_s} = \frac{R_c - R_s}{R_c} \dots \dots \dots (7)$$

Now the setting given the variable standard to secure a balance, and which we call the resistivity of the metal, will be directly proportional to the resistance of the metal between potential points. Hence $\rho_s \propto R_s$ and $\rho_c \propto R_c$ where ρ_s is the resistivity (which is the true resistivity obtained from Curve IV) obtained as the metal is heated, and ρ_c is the resistivity (apparent, which Curve II gives) obtained after the metal has solidified. We have thus

$$C_t = \frac{\rho_c - \rho_s}{\rho_c} \dots \dots \dots (8)$$

for any particular temperature below the solidification temperature. For a temperature of 1000°C . we find

$$C_{1000} = \frac{9.80 - 9.42}{9.80} = 0.0388 = \text{shrinkage in section at } 1000^\circ \text{C. when metal changes from liquid to solid.}$$

For a temperature of 20°C .

$$C_{20} = \frac{2.129 - 1.735}{2.129} = 0.185 +$$

These results may not mean much, but suggest interesting possibilities in the way of measuring the shrinkage of metals when they pass from liquid to solid.

The above discussion and the differences in the results recorded in Curve I, and in Curves II and III below the solidification point, raise the complex question as to what constitutes the true relation in these measurements between the resistivity on a basis of a constant mass and on a basis of a constant volume of the metal. A further discussion of the matter must be reserved until

the writer has obtained more facts and a clearer understanding of the interpretation to be put upon the observed data.

If we express the increase in resistivity of copper in the molten state by the relation

$$\rho_{t_1} = \rho_t \left[1 + \beta_t (t_1 - t) \right]$$

we find

$$\beta_t = \frac{\rho_{t_1} - \rho_t}{\rho_t (t_1 - t)} \dots\dots\dots (9)$$

where we are to understand by ρ_t the coefficient calculated when the lower temperature is t .

Let $t = 1100$ degrees. Then we find, calling $\rho_t = 21.43$ microhms,

$$\beta_t = \frac{23.39 - 21.43}{21.43(1340 - 1100)} = 0.000381.$$

In Table IV below those values are selected which, in the writer's judgment, have the highest probability of being correct.

TABLE IV.
Values Found for Copper of 99.39 Per Cent. Conductivity.

Tempera- ture de- grees C.	Resistiv- ity in mi- crohms per cm. cube	Ratios ρ_t/ρ_{t_1}	Notes
20	1.7347		
1000	9.42	$\rho_{1000}/\rho_{20} = 5.429$	Metal solid.
1082.6	10.20		
1082.6	21.30	$\frac{\rho_m}{\rho_s} = 2.088$	Metal molten.
1100	21.43		
1340	23.39		
1450	24.22	$\rho_{1450}/\rho_{20} = 13.96$	Highest measurement was 1443° C.

The writer expresses his indebtedness to his wife for her assistance in the laboratory, both in preparing for the measurements and in taking observations.

PALMER PHYSICAL LABORATORY,
PRINCETON, N. J.

Canadian Timber. ANON. (*Eng.*, xcvi, 2487, 289.)—The forests of Canada consist, for the greater part, of coniferous species; viz., pine and spruce, with hemlock on the east, and Douglas fir, western hemlock, and western larch in the west. In the east the hardwoods comprise poplar, birch, beech, and maple, with some elm, ash, and a few other minor species. Only in Southern Ontario is there anything like the variety of hardwoods which are found in the Appalachian region of the United States. The forestry branch of the Canadian Ministry of the Interior has established a system for the collection of statistics with respect to the various wood manufacturers of the Dominion. The quantities and values of the wood used in 1911 were: Lumber, 4,918,202,000 feet, of the value of \$75,830,954; square timber for export, 34,500 tons, worth \$766,406; lath, 965,235,000 pieces, valued at \$2,212,226; shingles, 1,838,474,000 pieces, worth \$3,512,078; pulp wood manufactured in Canada, 672,288 cords, of the value of \$4,388,024; pulp wood exported (unmanufactured), 847,939 cords, valued at \$5,340,592; cooperage (slack), 147,374,000 pieces, value \$1,465,702; cooperage (tight), 5,762,000 pieces, value not fully known; railway sleepers, 13,683,770 pieces, value \$5,237,424; and poles, 585,703 pieces, value \$1,056,277. The Douglas fir of the Western Provinces has made rapid progress, and now stands third in the list of lumber woods. Hemlock, once entirely passed by the log makers, now stands fourth in point of quantity sawn for lumber. While spruce still leads among woods used for pulp, balsam fir is also being more and more resorted to for the same purpose. For railway ties, jack pine has replaced cedar.

Reflection of X-Rays. M. DE BROGLIE. (*Nature*, xci, 161.)—This article includes interesting diagrams of the distribution of the pencils of X-rays due to the scattering of a very narrow beam by various crystals. The author considers that the transmitted "spots" of Friedrich, Knipping, and Laue are due to the same cause as the reflected spots obtained by allowing a beam of X-rays to fall on a face of a crystal at almost grazing incidence. The results show that spots produced on a photographic plate by the pencils scattered from the crystal are generally striated by parallel fringes both in the case of reflected and transmitted spots. Similar phenomena are obtained with ordinary light and two ordinary gratings (200 lines to the millimetre), when the incident beam forms similar angles of incidence with the plane of the gratings.

A New Soft Solder. ANON. (*Met. and Chem. Eng.*, xi, 8, 438.)—This new soft solder was patented by John T. Dwyer, of St. Louis, Mo., and is said to possess superior properties, and to be less costly than ordinary lead-tin solder. It contains approximately 41.5 per cent. of tin, 0.02 per cent. phosphorus, 2 per cent. antimony, and the balance is lead.

SOME PHENOMENA OF FLUID MOTION—THE CURVED FLIGHT OF A BASEBALL.*

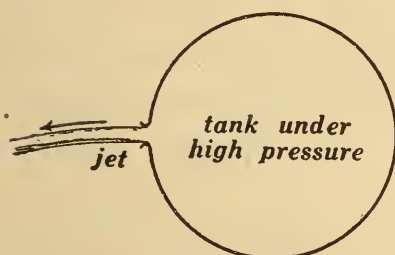
BY

W. S. FRANKLIN, Sc.D.,

Professor of Physics, Lehigh University.
Member of the Institute.

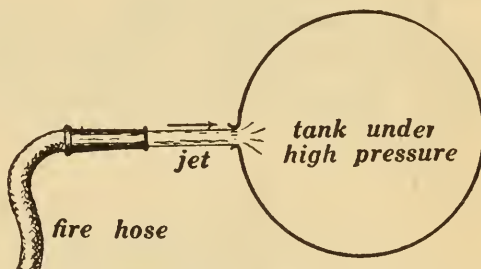
THE steady curvature of path of a rapidly spinning baseball in flight is explained on the basis of a principle which was first enunciated by Daniel Bernoulli several hundred years ago. Bernoulli's principle is illustrated in Figs. 1 and 2. In a stream of water or air the pressure is high where the velocity is low, and the pressure is low where the velocity is high. In the following discussion it is not desired to take account of gravity, and there-

FIG. 1.



In the tank the water has high pressure and low velocity; in the jet the water has low pressure and high velocity.

FIG. 2.



A fancy method for pumping water into a steam boiler. In the jet the water has high velocity and low pressure, and as the rapidly moving water pushes itself into the tank where the pressure is high it loses its velocity.

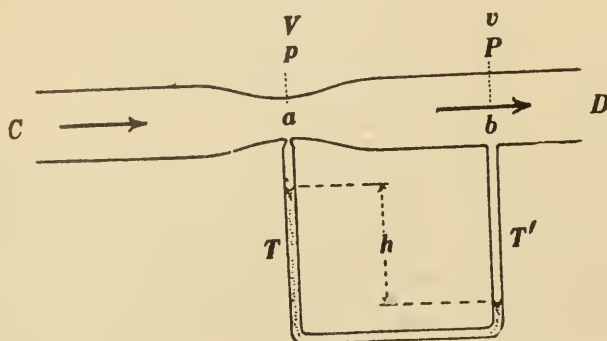
fore Bernoulli's principle is stated for the case of a horizontal stream. Also the effects of friction are ignored; as here stated, therefore, Bernoulli's principle applies only to approximately frictionless fluids, and indeed the principle applies only to cases of steady flow.¹

* Communicated by the author.

¹ A further limitation of Bernoulli's principle is exemplified by the motion of the fluid in a cream separator. The pressure is greatest near the outer walls of the rotating bowl where the velocity is greatest. Bernoulli's principle does not apply to rotational fluid motion.

THE VENTURI TUBE.—Air is blown through a tube CD (Fig. 3). The velocity of the air is larger at a than at b ; therefore, according to Bernoulli's principle, the pressure of the air is larger at b than at a . This excess of pressure at b is shown by the difference in level of the liquid in the two tubes T and T' .

FIG. 3.



If one blows hard enough through CD the liquid in T will be drawn up into the throat at a , where it will be broken up into spray.

THE DISK PARADOX.—A brass disk DD (Fig. 4) is soldered to the end of a tube T , and a light metal disk dd is held against DD by blowing strongly through T' . The region between the two

FIG. 4.

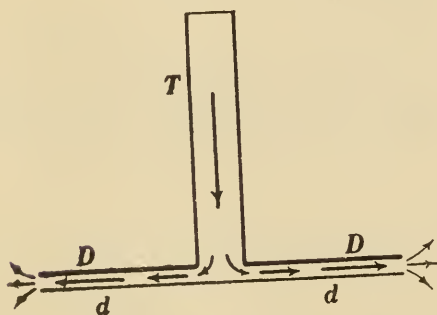
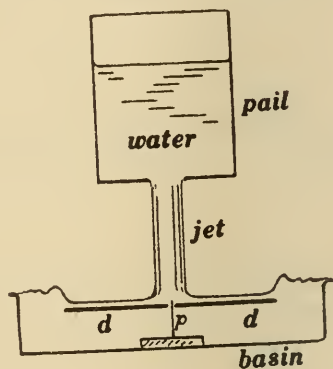


FIG 5.



disks is a region of high velocity, and as the stream comes out at the edge of the disks its velocity falls and its pressure rises, according to Bernoulli's principle. Therefore the pressure of the air in the region between the two disks is less than the pressure of the outside air, and consequently the outside air pressure holds the two disks together.

A complete hydraulic analogue of Fig. 4 is shown in Fig. 5.

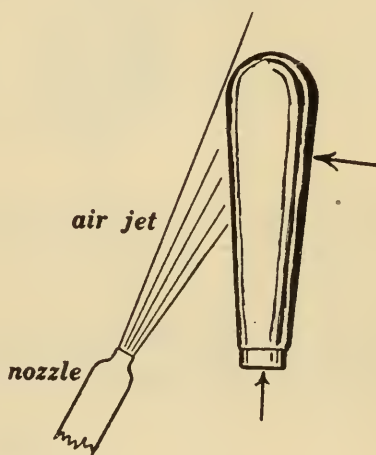
A thin metal disk *dd* is kept from moving sidewise by a pin *p* which projects through a small hole in the disk, and the disk is held up by the jet of water! The jet spreads out over the disk as a thin layer of rapidly moving water, and when this flowing water reaches the edge of the disk it loses its velocity and raises itself to the higher level of the still water in the basin.

THE BALL AND AIR JET.—A small ball floats steadily in an air or steam jet, as shown in Fig. 6. The impact of the jet against the ball holds the ball up, and when the ball starts to fall out of the jet, as shown in Fig. 6, it is pushed back into the jet because the

FIG. 6.



FIG. 7.



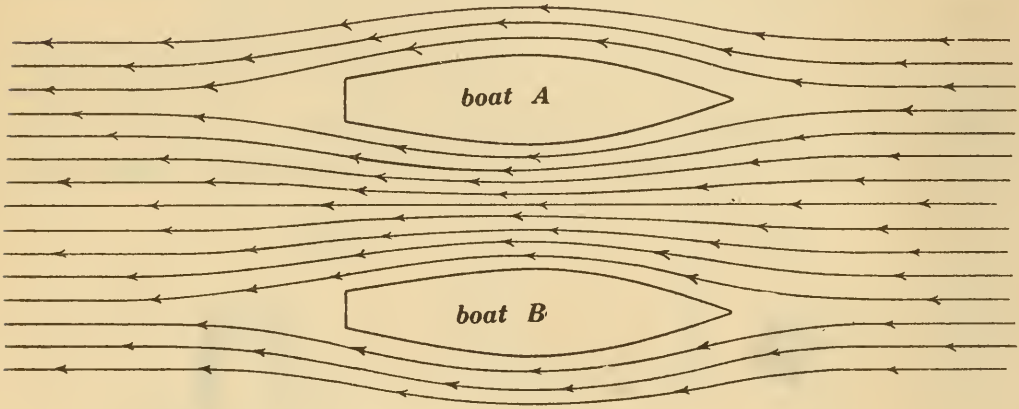
pressure of the surrounding still air is greater than the pressure of the rapidly moving air in the jet (Bernoulli's principle).

An ordinary file handle may be supported by an air jet, as shown in Fig. 7.

ATTRACTION OF TWO SHIPS STEAMING ALONG SIDE BY SIDE.—As a ship steams along through a body of still water, the water at a given point moves as the ship approaches, and comes to rest again when the ship is past. That is, the motion of the water is not what is called steady motion, and, therefore, Bernoulli's principle does not apply. But the dynamic effects associated with a ship steaming through a body of still water are exactly the same as the dynamic effects associated with a steady stream of water flowing past a ship which is standing still, and in the latter case the fluid motion is steady and Bernoulli's principle does apply. Thus Fig. 8 represents a stream of water flowing past two ships. The velocity of the water is greatest between the two boats where

the stream lines are most crowded. Indeed, the velocity of the water is greater between the boats than it is on the outer sides of the boats; therefore the level (pressure) of the water is greater

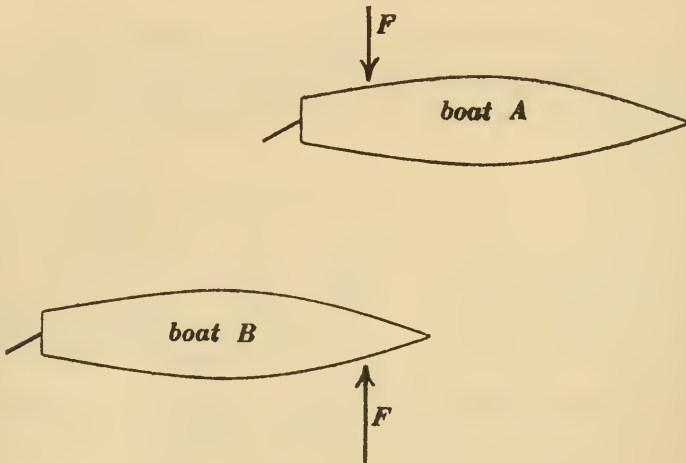
FIG. 8.



on the outer sides than it is between the boats; and consequently the two ships are pushed toward each other by the high-level water on the outer sides.

The most serious situation arising from the attraction of two moving ships is illustrated in Fig. 9. The forces FF in Fig. 9

FIG. 9.



tend to turn the ships, and these forces are apt to be much too large to be overcome by the action of either ship's rudder, even if the helmsmen are quick to set the rudders properly. Therefore ship *B* turns towards *A* and a collision results.

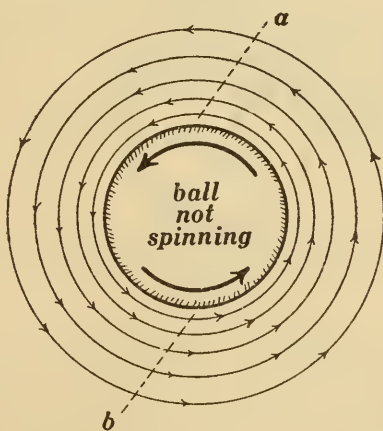
An experiment which illustrates the effects shown in Fig. 8 is to hang two smooth balls side by side, as shown in Fig. 10, with a space of about an inch between the balls; the balls are pulled together by blowing between them.

FIG. 10.



THE CURVED FLIGHT OF A SPINNING BALL.—To analyze the effect of the air upon a moving ball it is best to think of the ball as standing still with the air blowing past it, as shown in Fig. 12.

FIG. 11.

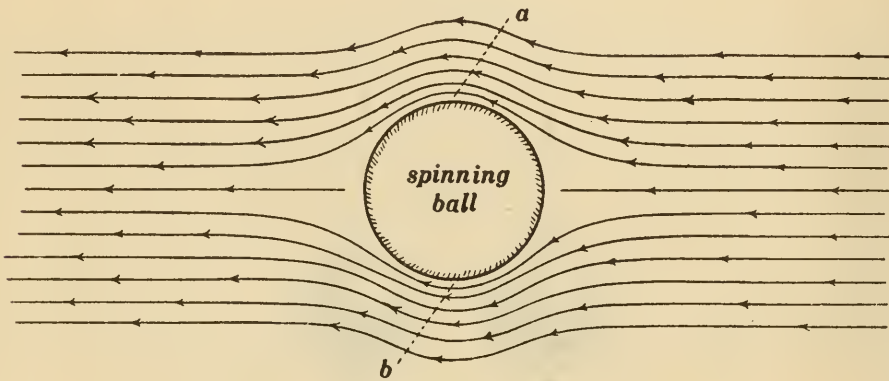


Air whirl produced near a spinning ball—air everywhere at rest except in so far as it is affected by the spinning ball.

Fig. 11 shows the air whirl near a spinning ball; and Fig. 12 shows a blast of air streaming past a ball that is not spinning. Let us consider a combination of Figs. 11 and 12,—that is, let us

consider how a blast of air streams past a spinning ball. At *a* the stream and the whirl both give a velocity from right to left,—that is, two causes are acting together at *a* to produce velocity from right to left. At *b*, on the other hand, the stream tends to

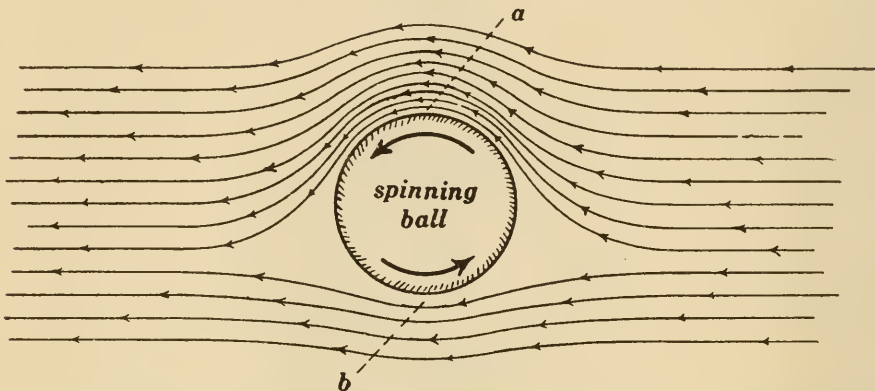
FIG. 12.



Air stream flowing past a ball which is not spinning.

produce a velocity from right to left, whereas the whirl tends to produce velocity from left to right,—that is, two causes act in opposition to each other at *b* to produce velocity. Therefore the velocity at *a* is much greater than the velocity at *b*, as shown in Fig. 13. Therefore, according to Bernoulli's principle, the

FIG. 13.



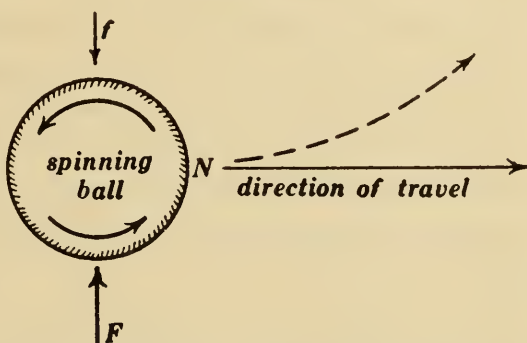
Air stream flowing past a spinning ball. The velocity is high at *a* and low at *b*; consequently the air pressure is high at *b* and low at *a*, thus producing the unequal forces *F* and *f* in Fig. 14.

pressure of the air at *b* is greater than the pressure of the air at *a*, and consequently the spinning ball is pushed upwards by the air stream or blast.

The dynamic effects in Fig. 13, where a blast of air blows from right to left past a spinning ball, are exactly the same as

the dynamic effects in Fig. 14, where a spinning ball moves from left to right through a body of still air. That is to say, the spinning ball in Fig. 14 is pushed upwards by the air, and therefore the ball travels in an upward curve, as indicated by the dotted curved arrow.

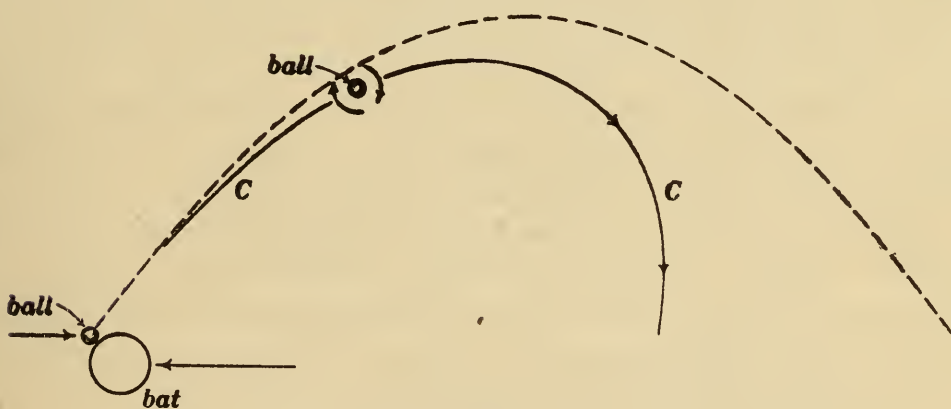
FIG. 14.



Unequal side forces f and F exerted on a spinning ball which is moving through the air.

Let us call the foremost point N of the travelling ball the *nose* of the ball. *The travelling ball curves in the direction in which the nose of the ball is moving because of the spin.* Thus, if the nose of the ball moves toward the right with respect to a

FIG. 15.



Curved flight of a high foul.

pitcher, the ball will curve to the right; if the nose of the ball moves upward (as shown in Fig. 14), the ball will curve upward, and so on.

Perhaps the best way to throw a curved ball for purposes of demonstration is to use a light ball of cork or pith and throw it from a pasteboard tube, moving the tube somewhat as one

would move a bat. The inside walls of the tube should be rough so that the ball will roll along the inside of the tube, and come out of the end of the tube with a rapid spinning motion.

Fig. 15 shows the curved flight of a high foul. The ball is set spinning rapidly as it glances off the bat, and instead of following the symmetrical dotted curve (which it would follow if it were not spinning) it actually follows the curve *CC*.

This curved flight of a high foul may be beautifully demonstrated by means of a light ping-pong ball or by means of an oak-gall. Throw the ball or oak-gall upward by the thumb as in shooting a marble, and as it falls it will curve in toward one's feet. This experiment must be performed in a closed room where there is no wind.

THE SPIT-BALL.—There is no reason why a sharp-pointed stick standing exactly vertical on a hard floor in a quiet room should fall one way more than another. Therefore the stick will not fall either way! That is good logic, but it is bad physics. The stick always does fall. The fact of the matter is that such a stick is unstable; and in the case of an ideally sharp stick standing perfectly vertical, an infinitesimal initial disturbance would be enough to start the fall in some direction, and then away she goes! We are here dealing with a kind of physical phenomenon in which the much-talked-of philosophical principle of cause and effect does not hold. When infinitesimal causes can determine finite differences in the ultimate trend of a phenomenon, then surely the principle of cause and effect is no more! Indeed, an infinitesimal cause is (in the limit) non-physical!

We here stand face to face with an entirely new branch of physical science, a branch which has existed for some years in the minds of some of our most advanced physicists, and a branch which is just beginning to be realized in researches concerning the discharge of electricity through gases: statistical physics. All correlations in this branch of physics must be sought for on the basis of statistical studies; the same thing never happens twice; and the old-fashioned idea of *cause and effect*, or the idea of *one-to-one correspondence*, or the idea of *law, in the sense of functional relationship* (as one may prefer to call it), gives place to chance and the laws of probability.

The older physics is sometimes called *macro-physics*, and the newer *micro-physics*; but this is distinctly misleading, because

the largest-scale phenomena with which we deal in this world of ours belong to statistical physics,—namely, weather phenomena. And the essential method in meteorology is the statistical method. Some little insight into atmospheric phenomena can be obtained by studying functional relationships, such as are expressed by Boyle's law of gases, the law of constant circulation in the vortex theory of fluid motion, the functional laws of radiation and absorption, and the functional relations of long-time and wide-space averages; but the thing which is now most needed in meteorology is the study and classification of storm types, the establishment of norms and probable departures therefrom, and, above all, the study of incipient stages of storm movements where very small variations may produce very large ultimate departures. If weather control is ever to be realized it must be by studying the possibilities of big consequences from small beginnings! Our Weather Bureau should employ, say, twenty of the most talented young men of highly-developed and rigorously-trained imaginative faculty, and set them to work studying storm data, averaging in time and space to discover norms, studying individual departures, and, above all, visualizing storm movements on a basis of the most minute study of details. No other method can ever lead to important results in meteorology.²

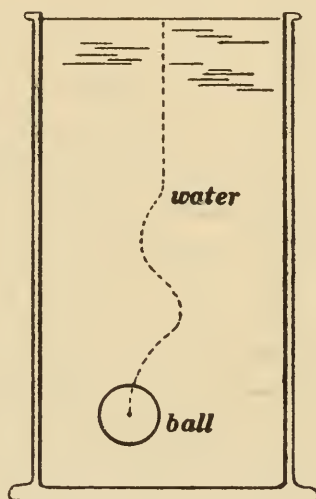
Consider a very smooth ball which is moving through still water without spinning. There is certainly no more reason why the ball should jump to the right than to the left. Therefore it must continue to move straight forward! That is good logic; but such a ball is no more subject to logic than is a sharp stick! The fact is that the ball does jump sidewise, and in a most irregular manner. This may be shown by dropping a smooth marble in a jar of still water. The marble goes nearly straight for several inches, and then suddenly jumps sidewise, as shown in Fig. 16. Similarly a smooth baseball jumps sidewise irregularly as it moves through the air, if the ball is not spinning.

Fig. 17 shows how a rapidly moving stream of air splits when it flows past a ball, and the dividing lines, or *vortex sheets*, *aa* and *bb* between moving and still air are unstable. The result is that the stream of air *aa* (or *bb*) spurts upward and downward in

² See a very brief article by W. S. Franklin in *Science*, vol. xiv, pp. 496, 497, September 27, 1901.

irregular succession. When the stream *aa* spurts downward it produces an upward force or reaction on the ball, and *vice versa*. That is to say, the irregularities of the streams *aa* and *bb* cause a series of irregular side forces to be exerted on the ball.

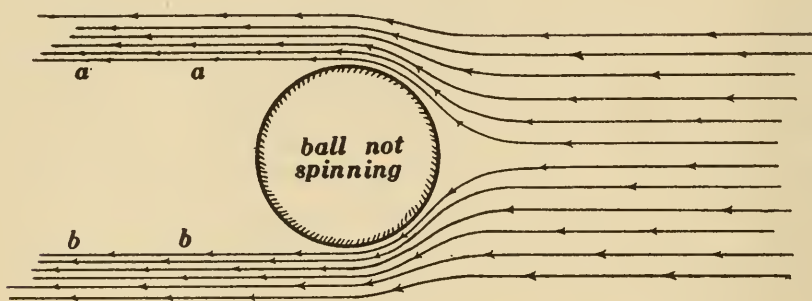
FIG. 16.



Irregular path of smooth ball (not spinning) as it sinks in water.

The dynamic effects associated with a ball standing in a stream of air as shown in Fig. 17 exist also when a ball moves through still air. Therefore if a ball moves fast enough through still air to produce unstable vortex sheets, the irregular sideways

FIG. 17.



Showing how a rapid stream splits when it flows past a ball.

spurts of the air as it flows around behind the ball will cause the ball to travel in an irregular zigzag path.

The instability and consequent irregularity of a stream of rapidly-moving fluid is exemplified by the sensitive flame. Every one knows how an ordinary gas flame suddenly becomes turbu-

lent and produces a roaring sound when it is turned up too high (velocity of gas too great), and when a gas flame is on the verge of becoming turbulent the least disturbance is sometimes sufficient to throw the flame over into the turbulent form. A sensitive flame can easily be made by drawing out a glass tube to give a smooth nozzle about a millimetre in diameter and burning a jet of ordinary illuminating gas at this nozzle. When properly adjusted the flame responds to a hissing sound across a large room.

The hissing sound of a high-pressure steam jet is due primarily to an unstable condition of the jet near the nozzle, an unstable condition which is somewhat similar to the instability of the vortex sheets *aa* and *bb* in Fig. 17; and this instability leads to an excessively irregular and complicated whirling and eddying motion in the jet. Indeed, a jet of gas or steam is infinitely complicated! Every one concedes the idea of infinity which is based on abstract numerals—one, two, three, four, and so on *ad infinitum*—and the idea of infinity which is based on the notion of a straight line; but most men are concerned with more or less persistent or steady phases of the material world, their perception does not penetrate into the substratum of utterly confused and erratic action which underlies every physical phenomenon, and they balk at the suggestion that the phenomena of fluid motion, for example, are infinitely complicated and erratic. Surely the abstract idea of infinity is nothing as compared with the dreadful intimation of infinity that comes from things that are seen and felt. We are immersed in an illimitable sea of phenomena every element of which is infinitely complex, and every minute detail is essentially erratic.

Noiseless City Streets. ANON. (*Sci. Amer.*, cix, No. 15, 279.)
—In Germany a cheap and ready method of asphaltting a stone-paved street is in use which shows good results. The spaces between paving blocks are cleaned out to the depth of an inch and then a layer of melted asphalt is flowed over the street surface to a depth of about one inch. Before it is cooled, sand is sprinkled on, and the surface is smoothed. A section of this kind is laid in Frankfort and appears to stand the wear remarkably well. Should it show success generally it will be an excellent means of deadening the noise of street traffic at a small expense. The process is quickly carried out and repairs are easily made.

Crystallization of Steel. F. GIOLITTI. (*Acad. Sci. Torino, Atti*, xlviii, 10a, 413.)—The author describes experiments which lead him to take a somewhat different view from that of Belaiew as to what occurs during the crystallization of steel. He concludes that there are two successive processes of crystallization: (1) The formation of mixed crystals of the fused metallic mass, and (2) the segregation of the ferrite or cementite from the solid solution. Contrary to Belaiew's results, slow cooling favors the formation of Widmanstätten's figures in steel containing about 0.32 per cent. carbon and heated to 1000° C. for eight hours, while rapid cooling renders them less perfect. Belaiew's hypothesis to explain the formation of Widmanstätten's structure and his theory of secondary crystallizations are not accepted.

Applications of Positive Rays to the Study of Chemical Problems. J. J. THOMSON. (*Cambridge Phil. Soc. Proc.*, xvii, 201.)—Two samples of gases obtained from the residues of liquid air are examined. One sample, treated so as to contain the heavier gases, is found to contain xenon, krypton, and argon. There are no lines on the photograph unaccounted for, hence it is concluded that there are no unknown heavy gases in the atmosphere in quantities comparable with the known gases. The other sample, treated so as to contain the lighter gases, is found to contain helium, neon, and a new gas with the atomic weight 22. The relative brightness of the lines for this gas and for neon shows that the amount of the new gas is much smaller than that of neon. The new gas, of atomic weight 3, which this method of analysis has shown to be present in the tube under certain conditions, is also investigated. The gas had occurred sporadically in the tube from the time of the earliest experiments, but its appearance could not be controlled. After a long investigation into the source of this gas, it is found that it always occurs in the gases given out by metals when bombarded by cathode rays; a trace of helium is also usually found on the first bombardment. The metals used are iron, nickel, zinc, copper, lead, and platinum. The gas is also given off by calcium carbide. Various experiments illustrate the stability of the gas.

Liquid Aluminum. ANON. (*Amer. Mach.*, xxxix, 3, 106.)—According to the German press, aluminum has been successfully brought to a liquid condition, so that it may be spread, when cold, over any dry surface. The composition is applied like a paint with a brush, and looks like a dull silver coating. It is said to be an excellent preventative of rust, to be resistant to heat, elastic, durable, and resistant to atmospheric influence, and to be an excellent substitute for tin in plating.

PROPORTIONING OF LONG-SPAN TRUSS AND CANTILEVER BRIDGES.*

BY

JOSEPH MAYER,

Assistant Engineer, Quebec Bridge Commission, Montreal, Canada.

W_i^c in (61a) is the weight of steel of one cantilever arm with erection of the suspended span by building out from the ends of the two cantilever arms. The weight does not include the erection material required; it includes only the steel remaining in the completed bridge. The main pier posts required for the loads coming from the cantilever arm and one-half the cross bracing between these posts are included.

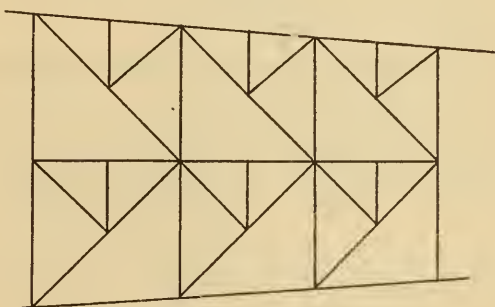
The other symbols in the formula (61a) are the same as in the formula (61), except that the h used in the calculation of A and B is here $h = 0.3804 l_c$.

$$\tan \beta \text{ for the subdivided K system} = \frac{4l}{0.3804l_c}$$

where l is the panel length and $2l$ the distance between succeeding main posts.

The subdivided K system is shown in Fig. 3.

FIG. 3.



The formulas (61) and (61a) are based on the assumption that the dead load per lineal foot of cantilever arm at its end is the same as the dead load per lineal foot of suspended span,

which is always approximately the case, and that the dead load d_x per lineal foot of cantilever arm at the distance x from its end is

$$d_x = \frac{d + 3.5d}{l_c} \cdot x$$

where d is the dead load per foot at end of cantilever arm.

This is not exactly true, but the ratio $\frac{W_p}{W_i}$ is so nearly alike for uniform loads and for loads increasing toward the pier that a considerable error in the assumed increase of dead load toward the pier will not materially affect its value.

The foregoing method of finding the weights of the trusses required for meeting the dead and live load stresses from different sources as directly as possible keeps the weights of the steel required for the different forces separate and makes it possible to judge the influence of the various forces. The influence of a change in width or of a change in the weight of the floor can be easily calculated.

When only the total weight of steel is wanted, all the vertical loads can be bunched together and the weight of the steel required to meet their stresses can be found by one calculation if the loads are known.

In the calculation of the stress sheets for ordinary spans the usual method adopted is to guess the dead loads, calculate the stresses, the sections, and the resulting weights; then the dead load assumed is corrected and the calculation is repeated with the corrected dead load.

In a cantilever arm the dead load is not uniform, but increases from the end toward the main pier.

The total load per lineal foot inclusive of the moving and impact load μ at the distance x from the end of the cantilever arm is

$$\mu + d_x = p + qx \dots\dots\dots (64)$$

In this equation $p = \mu + 0.97$ times the weight of the suspended span per lineal foot.

q is a constant which must first be guessed at. $q = \frac{2p}{l_c}$ is a good first guess for very long spans.

The total weight of the cantilever arm and of its moving load is then

$$W = \int_0^{l_c} (p + qx) \, dx = pl_c + \frac{ql_c^2}{2}$$

or

$$q = \frac{2}{l_c^2} (W - pl_c) \times 0.97 \dots \dots \dots (65)$$

The factor 0.97 is introduced with the dead loads because these call for about 3 per cent. less weight in the trusses than an equal amount of moving and impact load μ .

The equivalent weight at the end of the cantilever arm is

$$\frac{pl_s}{2}.$$

With the assumed q , the weight of steel in the cantilever arm with parallel chords is found to be

$$W_p^c = W_{\mu + dx} + F + W_{\omega} \dots \dots \dots (66)$$

In this equation

$$\begin{aligned} W_{\mu + dx} = \frac{l_c}{24} \bigg[& Al_c \{ 2p (3l_s + 2l_c) + ql_c^2 \} + 4B \{ 3p (l_s + l_c) \\ & + ql_c^2 \} \bigg] \dots \dots \dots (67) \end{aligned}$$

- A is given in equation (4).
- B is in equations (12), (13), and (14).
- l_c = length of cantilever arm.
- l_s = length of suspended span.
- F is the weight of steel in the floor of the cantilever arm.

W_{ω} is given in equation (53). After W_p^c is found the weight of timber, etc., in the floor and the moving load of the cantilever arm $= \mu l_c$ are added to obtain W , and with this the corrected q is obtained from equation (65).

With this the calculation of $W_{\mu + dx}$ is repeated by equation (67).

Another weight W and another q is obtained which may be used for one more calculation.

For inclined chords when

$$h_x = a + bx \dots\dots\dots (68)$$

where h_x is the height at the distance x from the end of the cantilever arm; with a load at the end of the cantilever arm equal to $\frac{pl_s}{2}$ and with a load per foot at the distance x from the end of the cantilever arm $= \mu + d_x = p + qx$, we obtain for the weight of the chords required to carry the vertical loads:

$$W_{i \text{ } ch}^{\mu + d_x} = (g_c + g_t) K \dots\dots\dots (69)$$

$$\text{where } g_c = \frac{3.4a_c \sec^2 \delta_c}{2U_c} \dots\dots\dots (70)$$

$$g_t = \frac{3.4a_t \sec^2 \delta_t}{2U_t} \dots\dots\dots (71)$$

$$K = \frac{1}{3} \left(\frac{ql_c^3}{3b} + \frac{(3bp - aq)l_c^2}{2b^2} + \frac{3pl_s - 3abp + aq^2}{b^4} \times \right. \\ \left. 2.3026a \log \frac{h_p}{a} \right) \dots\dots\dots (72)$$

For the weight of the webs we find

$$W_{i \text{ } web}^{\mu + d_x} = \frac{B}{6} \left\{ 3pl_c(l_s + l_c) + ql_c^3 - 3bK \right\} \\ + \frac{3.4a_{c2}l_c \left\{ 3p(l_s + l_c) + ql_c^2 \right\} \tan \delta_t}{6U_{c2}} \dots\dots (73)$$

B is to be taken at a distance of about $\frac{1}{4}l_c$ from the main pier.

U_{c2} = axial unit stress in the pier post.

h_p = height of truss at the main pier; $h_p = a + bl_c$; $a_{c2} \approx 1.5$.

δ_t and δ_c are the angles of the tension and compression chords respectively with the horizontal.

For the weight of steel in the cantilever arm we obtain

$$W_i^c = F + W_\omega^1 + W_{i \text{ } ch}^{\mu + d_x} + W_{i \text{ } web}^{\mu + d_x} \dots\dots\dots (74)$$

After this weight is found the total weight of the cantilever arm and of its moving load is calculated and a corrected value of q determined with which the calculation is repeated.

CANTILEVER ARMS WITH CURVED CHORDS.

The foregoing formulas for the weight of steel of a cantilever arm only apply with straight chords.

With curved chords the fundamental formulas for the weight of the chords and the webs which apply generally to all trusses must be used.

Since the height and the angle β of the diagonals with the vertical change with every main panel, the general formulas must be used for each main panel in succession and the results added.

With horizontal bottom chords the laterals and the cross bracing can be calculated in one operation for the whole cantilever arm.

For the weight of parallel chords of one panel we have :

$$W_{p.ch} = M_a \cdot A = M_a \frac{3.4}{h} \left(\frac{a_t}{U_t} + \frac{a_c}{U_c} \right)$$

where M_a is the moment area for the panel.

When the chords are inclined the chord stresses and the lengths of the chords are increased. If the angles of the chords with the horizontal are δ_c and δ_t , then the formula for the weight of the chords in the panel becomes

$$W_{i.ch} = M_a \frac{3.4}{h} \left(\frac{a_t \sec^2 \delta_t}{U_t} + \frac{a_c \sec^2 \delta_c}{U_c} \right) \dots\dots\dots (75)$$

Here h is the height at the centre of the main panel.

The moment area M_a is approximately equal to the moment at the centre of the panel length multiplied by the panel length.

When p is the total equivalent load per foot of suspended span and $p_x = p + q \cdot x$ is the load per lineal foot at the distance x from the end of the cantilever arm, then the moment M_x at the distance x from the end of the cantilever arm is

$$M_x = \frac{p \cdot x (l_s + x)}{2} + \frac{qx^3}{6} \dots\dots\dots (76)$$

We have, therefore, for the weight of the chords of one panel

$$W_{i.ch} = \left\{ \frac{px(l_s + x)}{2} + \frac{qx^3}{6} \right\} \frac{3.4l}{h_x} \left\{ \frac{a_t \sec^2 \delta_t}{U_t} + \frac{a_c \sec^2 \delta_c}{U_c} \right\} \dots (77)$$

where h_x is the height at the centre of the main panel at the distance x from the end of the cantilever arm. For the weight of the web with parallel chords we have

$$W_{p.web} = S_a B$$

With inclined chords the chords carry a part of the shear, and the shear of the web is equal to the total shear, less the shear in the chords.

The total shear S at the distance x from the end of the cantilever arm is

$$S = p \left(\frac{l_s}{2} + x \right) + \frac{qx^2}{2} \dots \dots \dots (78)$$

The shear S_{ch} in the two chords is

$$S_{ch} = \left\{ \frac{px(l_s + x)}{2} + \frac{qx^3}{6} \right\} \frac{\tan \delta_t + \tan \delta_c}{h_x} \dots \dots \dots (79)$$

The web shear S_{web} is, therefore,

$$S_{web} = p \left(\frac{l_s}{2} + x \right) + \frac{qx^2}{2} - \left\{ \frac{px(l_s + x)}{2} + \frac{qx^3}{6} \right\} \frac{\tan \delta_t + \tan \delta_c}{hx} \dots \dots \dots (80)$$

The shear area of the web is

$$S_{web}^a = S_{web} \cdot l \dots \dots \dots (81)$$

where l is the length of the main panel.

The weight of the web is $W_{i.web} = S_{web} \cdot lB \dots \dots \dots (82)$

The weight of the laterals and the cross bracing is found by the formulas previously given for cantilever bridges with straight chords.

Formula (53) applies without change with straight horizontal bottom chords.

In other cases slight modifications for the length easily found will serve. After the weight of the steel in the cantilever arm has been obtained its total weight is easily found. The value of q , which was first guessed to be $q = \frac{2p}{l_c}$, is then found by formula (65), and the calculation may have to be repeated with the corrected q .

The formulas here given for the web of a panel of the cantilever arm include with each panel one-half the weight of the two limiting verticals, if such occur in the design, but they do not include that part of the pier post which is needed for the stress coming from the top chord of the cantilever arm.

The shear in the top chord at the main pier is

$$S_{pp} = \left\{ \frac{pl_c (l_s + l_c)}{2} + \frac{ql_c^3}{6} \right\} \frac{\tan \delta_t}{h_p}$$

The weight of this part of the pier post is approximately

$$W_{pp} = \frac{S_{pp} h_p \cdot 3.4 \times 1.5}{U_{c2}}$$

The calculations by means of the foregoing formulas are so simple that it is easily practicable to calculate the weights for various lengths of the suspended span, panel lengths and heights and to find thus the most economical design of the main span.

The design of the anchor arm is quite similar to that of the cantilever arm, and similar formulas might be derived for its weight after that of the main span and the pier moment are known.

An anchor arm five-sixths as long as the cantilever arm weighs with the anchorage, for the longest spans, if made of the same material as the main span, about the same as the cantilever arm.

The weight of the shoes, if of the same material as the rest of the bridge, is about 3 per cent. as much.

From numerous calculations for designs of cantilever bridges with main spans of 1400 to 2000 feet the following results referring to the best general dimensions were obtained.

The most economical height at main piers fluctuates to both

sides and near one-sixth the length of the main span. It is also influenced by the panel length, the nature of the web system, and by the curvature of the chords. It increases with the panel length, and is larger with inclined posts and a double system of web members than with vertical posts or with a single system of inclined posts with numerous vertical subposts. It is also larger with the K system of web members than with the same moderate panel length and other web systems; it is more with curved than with straight chords. The best height at the main piers is largest with very long panels near the piers and with double intersection web with inclined posts and with curved chords as in the Forth Bridge. Such a panel length is, however, unsuitable for shop manufacture and erection by means of an erection traveller.

Both the published designs for the new Quebec bridge are too high at the piers for the best economy of weight. Their great height was chosen to reduce the required cross section of the heaviest bottom chords. The influence of the height at the main pier on the economy of weight is very small so long as the deviation from the most economical height does not exceed about 5 per cent.

A small height at the end of the cantilever arm is economical for its weight. The best average panel length in feet for very long double-track spans is

$$\frac{4L}{300} + 27,$$

where L is the length of the main span in feet.

PRIMARY UNIT STRESSES.

It is a common practice to prescribe for ordinary spans a certain unit stress, differing for compression and tension members, for the sum of dead + live + impact stress and another unit stress 25 per cent. larger for dead + live + impact + wind stress. This gives in different members unit stresses varying by 25 per cent., according to the proportion of the wind stress.

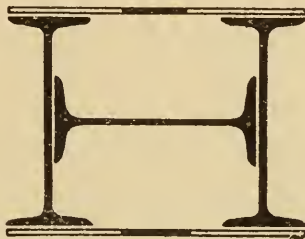
A scientific design calls for a uniform factor of safety and a uniform unit stress in members of the same nature. This result is only secured by determining the sections by dividing the sum of all the axial compression by a permissible axial unit stress obtained

from a total unit stress for compression, reduced for length of member in long members, and for bending stress due to weight of member.

Recent tests show for full-sized compression members made of two channels latticed on the two open sides smaller ultimate strength than was previously often assumed. They have also shown that H sections composed of three built or rolled I beams, with the open sides latticed, are about 15 per cent. or more stronger than the former sections. It would, therefore, be reasonable to use 15 per cent. more unit stress in the latter than in the former sections.

Full-sized eyebars are about 10 per cent. stronger than riveted tension members: larger unit stresses in the former than in the latter are, therefore, justified.

FIG. 4.



These facts were kept in mind in the selection of the unit stresses for the examples given. The writer would adopt for all bridges of carbon steel 20,000 pounds tension per square inch for the sum of all axial stresses in eyebars.

18,000 pounds in riveted tension members.

14,000 pounds per square inch gross in short struts made of two channels latticed.

$$17,500 - 70 \frac{l}{r}$$

in long ones and 15 per cent. more in struts made of 3 I beams latticed at the open sides, as in Fig. 4.

From these unit stresses for compression members, for the sum of all the stresses, the bending stress due to weight of member should be subtracted to obtain the proper axial unit stress.

These unit stresses should only be used for determining the sections where the secondary stress is not more than one-third of the primary stress.

Theoretical considerations, and the experiments with eyebars after Mr. Theodore Cooper and Colonel Howard led to the conviction that the ultimate strength of all tension members and the practical elastic limit of slender tension members are not affected by the amount of the coexisting cross bending produced by their own weight. To confirm this theory, the Board of Engineers of the Quebec Bridge had identical bars pulled apart while their weight was counterbalanced at numerous points, and while they were so cross-loaded as to produce equal bending moments as the weights of the longest bars when in the bridge. The tests showed that the ultimate strength and the elastic limit were not reduced by the cross-loading. For this reason the bending stresses due to the weight of tension members were neglected in all the foregoing calculations, while they were considered in all the compression members.

SECONDARY STRESSES.

The usual methods of calculating the stresses of riveted and pin-connected truss bridges assume that there are perfect frictionless hinges at the panel points and that the centre lines of gravity of all the members meet in the centres of these hinges. If such hinges and centric connections did exist, loads applied at the panel point would produce only axial tensions and compressions in the truss members.

The weights of the individual members would, however, produce bending stresses in them. These axial and bending stresses which would exist if there were perfect hinges at the panel points are called primary stresses. The absence of perfect hinges has three effects. It vitiates the calculation of the axial primary stresses. It greatly modifies the bending stresses due to weight of member, and it introduces additional bending stresses, called secondary stresses. If these secondary stresses are large the primary axial stresses of some of the minor truss members are changed considerably, but no short and accurate method of calculating these changes exists. The bending stresses due to weight of member which result from the absence of perfect hinges can be easily calculated, and it is best to calculate these modified bending stresses due to weight of member and to consider them

as the primary bending stresses. They are the only stresses which can be accurately calculated.

We are obliged to use the axial primary stresses as if they did really exist, since they are the closest approximation to the really existing axial stresses which we can obtain. By use of the best available methods for reducing those secondary stresses which coexist with the maximum primary stresses the errors in these most important primary stresses can be kept within narrow limits.

Large secondary stresses coexisting with the maximum primary stresses greatly increase the maximum total stresses and they make it impossible to calculate these maximum total stresses with the desirable accuracy. They should, therefore, be avoided wherever this is possible.

The size of the secondary stresses greatly depends in cantilever and anchor arms on the curvature of the chords, and in all bridges on the kind of web system used, and on the ratio of $\frac{e}{l}$ where e is the distance from the neutral axis of a member to the extreme fibres of its cross section, measured in the plane of the truss. To obtain small secondary stresses this ratio should be less than one-eighteenth, which can be easily accomplished.

If the lengths of the members of a riveted span are so chosen that the continuous straight chords and the web members have their panel points in straight lines for full live load, and if the connections are so designed that with this loading the end bending moments in the web members are 0, then the secondary stresses due to vertical loads occur during erection and are 0 with full live load. This requires the use of drift pins to force the members into position during erection, and is for this reason, in ordinary spans where the secondary stresses are small, generally avoided.

If pin-connected spans are erected with lubricated pins and swung free from the scaffolding before riveting up the top chord splices, and if the lengths of the members give the geometrical shape of the truss, assumed in the design of the splices, under dead load stresses, then there arise no secondary stresses from dead load. Those from moving load, wind stresses and differences of temperature are in ordinary spans moderate and are in them generally neglected.

Quite considerable secondary stresses arise from differences

of temperature of different parts of the same compression member when some are in the shade and some in the sun.

The sum of all the secondary stresses in fully stressed riveted chords of well-designed ordinary spans, coexisting with maximum primary stresses, seldom much exceeds one-third of the primary stresses. In eyebar chords and in slender diagonals with a small ratio of $\frac{e}{l}$ the secondary stresses are smaller.

In vertical posts with the floor beams riveted to them the sum of the secondary stresses often much exceeds one-third the sum of the coexisting maximum primary stresses. If secondary stresses are not otherwise considered it would be desirable to reduce the primary unit stresses in these posts to about three-fourths of those in compression chords with the same ratio of $\frac{l}{r}$. These posts very often have surplus sections. The fact that they are safe in spite of a very large percentage of secondary stress does, therefore, not prove that fully-stressed members would be equally safe with the same ratio of secondary stresses.

In ordinary spans it is common practice to neglect the secondary stresses, and experience shows that they are safe with the unit stresses in common use, say those of the American Railway Engineering Association.

This shows that the steel at present in use can safely carry the usual primary stress plus secondary stress amounting to about one-third as much.

If the bridges of unusual or unprecedented dimensions are so designed with the common primary unit stresses that the sum of all the secondary stresses does nowhere exceed one-third of the coexisting maximum primary stresses they will be safe.

There is no good reason for taking larger unit stresses in long than in short spans, provided that in both the moving load and wind pressure assumed are equal to the largest actual loads which will ever come on the bridge, and provided that the impact and secondary stresses are correctly calculated for both.

The neglect of the secondary stresses in long spans is only justified if it can be proven that they are no larger, compared with the coexisting maximum primary stresses, than in spans of ordinary dimensions which have been proven safe by past experience. The only way to prove this is to calculate the secondary

stresses wherever there is reason to believe that they may exceed one-third the maximum coexisting primary stresses. Where such excess occurs the sections should be increased until the total stress does not exceed by more than one-third the permissible primary unit stress.

Unless special measures are taken to prevent it, several features of long-span cantilever bridges largely increase the secondary stresses.

First.—The long and comparatively shallow floor beams of very long spans cause by their deflection, if riveted to the posts, much larger secondary stresses in them than the shorter, relatively deep floor beams of short spans.

Second.—In very long spans the main posts are made of four webs, and they are very broad, measured in the direction of the floor beams. This also increases their secondary stresses arising from the deflection of the floor beams.

Both these facts result in large end moments of the floor beams requiring special end connections to provide for them. In many cases hinged connections of the floor beams to the posts are the only effective remedy for excessive secondary stress from these causes.

Third.—The four webs of the posts and the chords largely increase their secondary stresses arising from wind stresses and from difference of temperature of the parts in the sun and those in the shade.

Fourth.—Unless all the truss members of cantilever bridges are hinged to the main shoes, large secondary stresses arise at the shoes in the truss members.

Fifth.—If the suspended span is carried by eyebar hangers extending from the ends of its bottom chords to the ends of the top chords of the cantilever arms large secondary stresses arise in them from changes of temperature and moving load.

Sixth.—The large dimensions of the bottom chords of the cantilever and anchor arms result, if they are supported at every panel point, in a large ratio of $\frac{e}{l}$ and consequently in large secondary stresses.

The measures taken to reduce excessive secondary stresses coexisting with maximum primary stresses are as follows:

First.—The lengths of all the truss members are so chosen

that the trusses have their geometrical shape assumed in the design of the chord and post splices and of the riveted connections, when the main span is fully loaded, which gives maximum chord stresses with small coexisting secondary stresses from vertical loads.

Second.—The pins are lubricated with graphite so that the members adjust themselves, at least from the time of putting them into place to the completion of the erection, thereby reducing the secondary stresses due to pin friction.

Third.—All the truss members are hinged at the main shoes by means of large pins and thimbles or sleeves to reduce the unit pressures and to facilitate the adjustments, which is here of special importance

Fourth.—Such thimbles, here of manganese bronze, are also used between the pins and the holes of the eyebar suspenders carrying the suspended span.

Fifth.—The floor beams when riveted to the posts have their end connections so designed that their end moments are 0 for dead load plus one-half. This reduces the bending moment in the posts, from the deflection of the floor beams, to less than half that with the usual design.

Sixth.—Where this bending moment would still produce too large secondary stresses in the posts, the floor beams are connected to them by hinges.

Seventh.—Where the bottom chord sections of the cantilever and anchor arms are large the chords are held only at every second panel, thus reducing the ratio $\frac{e}{l}$ and still more the resulting secondary stresses. By these measures it is practicable to reduce the secondary stresses in all but a few members to less than one-third the coexisting maximum primary stresses. Where this is impossible the sections should be increased by the proper amounts.

If the secondary stresses are not thus provided for, many of them which would not recur after a single overstraining of the metal beyond its elastic limit are probably practically harmless, but those caused by alternating stresses overstraining the metal alternately in opposite directions would probably shorten the life of the bridge and might even endanger its safety.

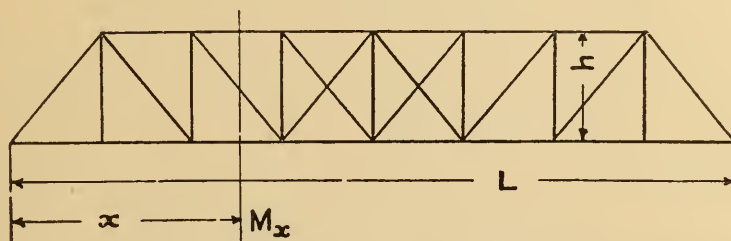
The only certainly safe course is, therefore, to provide additional sections at least for those secondary stresses which exceed the coexisting maximum primary stresses by more than one-third.

APPENDIX A.

DERIVATION OF FORMULAS FOR ORDINARY TRUSSES.

Let us consider a bridge truss with parallel chords (see Fig. 5) acted upon by a uniform moving load equal unity per lineal foot

FIG. 5.



of truss. All the chord stresses are maxima when the bridge is fully loaded. The end reaction is $\frac{L}{2}$ and the moment at distance x from the end of the span is

$$M_x = \frac{L}{2} x - \frac{x^2}{2} = x \frac{(L - x)}{2}$$

The chord stress at panel points is

$$\frac{M_x}{h} = \frac{x (L - x)}{2h}$$

The area of the compression chord is approximately $\frac{x (L - x)}{2 h U_c}$; that of the tension chord $\frac{x (L - x)}{2 h U_t}$ where U_c and U_t

are the axial unit stresses for compression and tension respectively. In bridges with long panels the bending stresses per square inch in compression members due to their weight are important and must be subtracted from the permissible total unit stress. The weight of the compression chord is approximately

$$W_{ch}^c = \int_0^L \frac{3.4 a_c}{2 h U_c} x (L - x) dx$$

or

$$W_{ch}^c = \frac{3.4 a_c L^3}{12 h U_c}$$

The weight of the tension chord is

$$W_{ch}^t = \frac{3.4 a_t L^3}{12 h U_t}$$

and the weight of both chords is

$$W_{ch} = \frac{3.4 L^3}{12 h} \left\{ \frac{a_c}{U_c} + \frac{a_t}{U_t} \right\} = \frac{A L^3}{12}$$

$$\text{Where } A = \frac{3.4}{h} \left\{ \frac{a_c}{U_c} + \frac{a_t}{U_t} \right\} \dots\dots\dots (4)$$

a_c and a_t are:

$$a_t = \frac{\text{weight of tension chord panel}}{3.4 \times \text{its required net area in square inches} \times \text{length in feet}}$$

$$a_c = \frac{\text{weight of compression chord panel}}{3.4 \times \text{its required gross area in square inches} \times \text{length in feet}}$$

h and L are given in Fig. 5

Another instructive method of obtaining this formula is as follows: The moment at distance x from the end of the span is

$$M_x = \frac{x (L - x)}{2}$$

If the moments are entered as ordinates to the corresponding values of x as abscissæ we obtain a moment curve, and between it and the axis of abscissæ a moment area.

An element of this area is

$$\frac{x (L - x)}{2} dx$$

The whole area is

$$M_L^a = \int_0^L \frac{x (L - x)}{2} dx = \frac{L^3}{12}$$

The average moment or the average ordinate of the moment curve is $\frac{L^2}{12}$. The average chord stress for a uniform height h is $\frac{L^2}{12 h}$.

The average compression chord section is $\frac{L^2}{12hU_c}$

The weight of the comparison chord is, therefore,

$$W_{ch}^c = \frac{3.4L^3\alpha_c}{12hU_c}$$

and the weight W_{ch} of both chords is

$$W_{ch} = \frac{3.4L^3\alpha_c}{12h} \left\{ \frac{\alpha_c}{U_c} + \frac{\alpha_t}{U_t} \right\} \text{ as above.} \dots\dots\dots (4a)$$

This derivation shows that the weight of the chord is obtained by multiplying the moment area by

$$\frac{3.4}{h} \left\{ \frac{\alpha_c}{U_c} + \frac{\alpha_t}{U_t} \right\} = A \dots\dots\dots (4)$$

The moment area used in the formula is that of the loads shown by the parabola of Fig. 6.

The actual moments determining the top chord sections of each half of the truss are given by the polygon $b_1b^1cc^1dd^1ee_1b_1$.

The moment area used in the formula for the weight of the chords is that between the parabolic arc shown and the axis of x .

In Fig 6, $\left\{ \begin{array}{l} \text{the triangle } edd^1 = \frac{L}{16} \cdot \frac{1}{16} ee_1, \\ \text{the triangle } dcc^1 = \frac{L}{16} \cdot \frac{3}{16} ee_1, \\ \text{the triangle } cbb^1 = \frac{L}{16} \cdot \frac{5}{16} ee_1, \\ \text{the triangle } bb_1a = \frac{L}{16} \cdot \frac{7}{16} ee_1. \end{array} \right.$

The correct moment area of the top chord of each half span is that of the parabola + the triangles

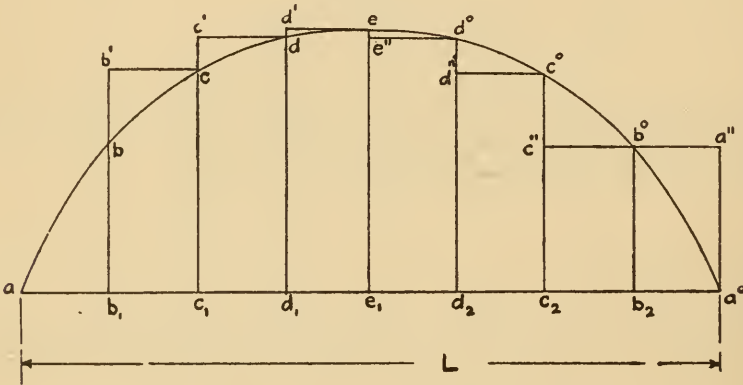
$$edd^1 + dcc^1 + cbb^1 - bb_1a = \frac{L}{16} \times \frac{1}{8} ee_1.$$

The area of the polygon representing the correct moment area of the whole top chord is, therefore, equal to the area used in the formula $+\frac{L}{64}ee_1$. The area of the parabola is two-thirds Lee_1 .

The actual area is, therefore, nearly 2.35 per cent. larger than the area used in the formula.

The polygon in the right-hand half of Fig. 2 gives the actual moment area for the bottom chord. This is over 2.35 per cent.

FIG. 6.



smaller than the area used in the formula. The error made in the sum of the weights of the two chords by using the formula above given is $\frac{1}{2}$ per cent. the result found by the formula being $\frac{1}{2}$ per cent. too small. With more panels the percentage of error is smaller. The size of the error for other systems of web members can be easily ascertained in a similar manner. It is never large enough to affect the argument.

The shear at the distance x from the end of the span with this distance x loaded with unit load per foot of truss is

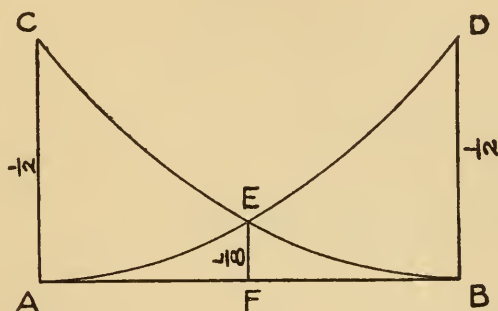
$$Sx = \frac{x^2}{2L}$$

The total shear area when x increases from 0 to L is

$$S_L^a = \int_0^L \frac{x^2}{2L} = \frac{L^2}{6}$$

The same area is obtained when the train moves in the opposite direction. The total shear area for both directions of motion is, therefore, $\frac{L^2}{3}$. The area $AEBA = \frac{L^2}{24}$ (see Fig. 7) gives the negative shears included in $\frac{L^2}{3}$.

FIG. 7.



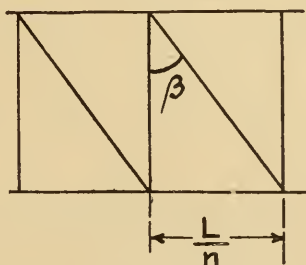
The positive shear area is $ACEDBA = \frac{7}{24} L^2$.

Taking both positive and negative shears, we obtain $\frac{L}{3}$ as the average shear from a unit moving load.

The average stress in the web diagonals is $\frac{L}{3} \sec \beta$. The sum of the lengths of all the diagonals for n panels is $L \operatorname{cosec} \beta$.

The average net area of a diagonal is $\frac{L \sec \beta}{3 U_h}$.

FIG. 8.



The weight of the diagonals is

$$W_d = \frac{3.4 L^2 a_h \sec \beta \operatorname{cosec} \beta}{3 U_h} = \frac{2 \times 3.4 L^2 a_h}{3 U_h \sin 2\beta}$$

Where U_{t_1} is the axial unit stress of the diagonals per square inch of net section and

$$a_{t_1} = \frac{\text{weight of diagonal}}{3.4 \text{ net section required in square inches} \times \text{length in feet.}}$$

The average shear is $\frac{L}{3}$; this is also the average vertical post stress.

The average post section is $\frac{L}{3U_{c_1}}$

The length of one post is $\frac{L}{n} \cot \beta$

The length of n posts is $L \cot \beta$.

The weight of n average posts is

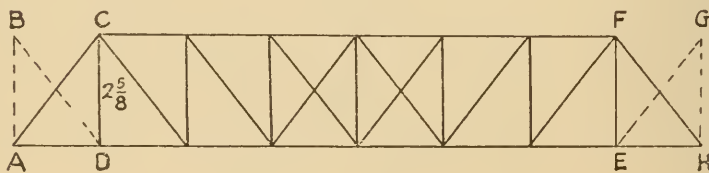
$$\frac{L}{3U_{c_1}} L \cot \beta \cdot 3.4 a_{c_1} = \frac{3.4 L^2 a_{c_1}}{3U_{c_1} \tan \beta}$$

The weight of the diagonals and counters of n panels and of n average posts is

$$\frac{3.4 L^2}{3} \left\{ \frac{2 a_{t_1}}{U_{t_1} \sin 2\beta} + \frac{a_{c_1}}{U_{c_1} \tan \beta} \right\}$$

The formula gives the weight of all the diagonals of Fig. 9 inclusive of the two dotted end diagonals and of the posts of the

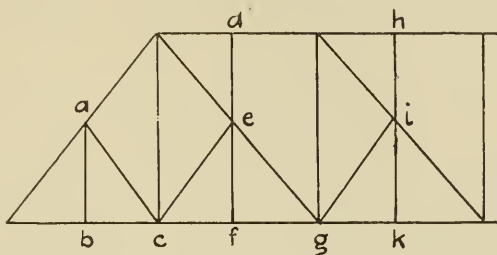
FIG. 9.



truss plus 3 posts AB , CD , and FE , but does not include the end posts AC and FH and the hangers CD and FE of the actual truss. The members included in the formula do not entirely cover the member omitted. To obtain good floor-beam connections and a satisfactory $\frac{l}{r}$ for the posts near the centre of the span, these latter have in short spans a large surplus of section.

In long spans (see Fig. 10), where the main diagonals go over two panels, the sub-posts ac , ce , gi , ed , hi , etc., and the sub-hangers ab , ef , ik , are not included in the formula.

FIG. 10.



To allow for these deficiencies the coefficient in front must be increased from 3.4 to 4 to obtain approximately correct results.

The formula is then

$$W_{web} = \frac{4}{3} L^2 \left\{ \frac{2 \alpha_{t_1}}{U_{t_1} \sin 2\beta} + \frac{\alpha_{c_1}}{U_{c_1} \tan \beta} \right\} \dots\dots\dots (12a)$$

The formula is approximate for uniform unit compressions in all the posts and uniform unit tension in all the diagonals. The formula must otherwise be used with the average unit stress in the tension members and the average unit stress in the compression members.

It shows that the weight of the diagonals is a minimum for $\beta = 45^\circ$ and the weight of the posts for the longest panels.

$$\text{If } B_v = 4 \left\{ \frac{2 \alpha_{t_1}}{U_{t_1} \sin 2\beta} + \frac{\alpha_{c_1}}{U_{c_1} \tan \beta} \right\} \dots\dots\dots (12)$$

we have

$$W_{web} = B_v \frac{L^2}{3},$$

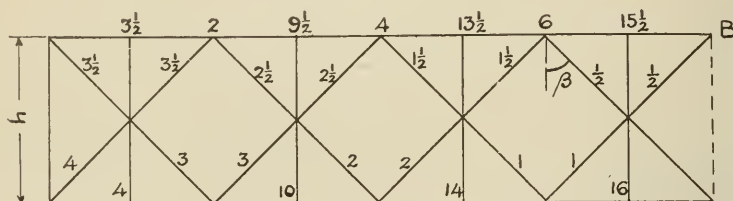
or the weight of the web is equal to B_v multiplied by the shear area.

Especially for deck bridges with the floor beams resting on the top chords, single web systems with inclined posts (Warren trusses) for short and double web systems with inclined posts for long spans are most economical in weight and give a good design, especially with the floor beams resting on the top chords. It is, therefore, of interest to obtain the formulas for the weights of such trusses.

The stresses in the chords are maxima for full load. Fig. 11 shows one-half of a truss with 16 panels. For a unit load per foot of truss the panel load is $\frac{L}{16}$. The chord stresses are obtained by multiplying the figures given on the chord panels by

$$\frac{L}{16} \cdot \frac{L}{8h}.$$

FIG. 11.



The weight of the top chords is, therefore,

$$\frac{2L^2 3.4}{128h} \left\{ 3\frac{1}{2} + 9\frac{1}{2} + 13\frac{1}{2} + 15\frac{1}{2} \right\} \frac{L}{8} \cdot \frac{a_c}{U_c}$$

$$W_{ch}^c = \frac{3.4 \times 42 a_c L^3}{512hU_c} = \frac{3.4L^3 a_c}{12.19hU_c}$$

The weight of the tension chords is

$$W_{ch}^t = \frac{3.4L^3 \times 44 a_t}{512hU_t} = \frac{3.4L^3 a_t}{11.64hU_t}$$

The previously given formula for both chords is

$$W_{ch} = \frac{3.4L^3}{12h} \left\{ \frac{a_c}{U_c} + \frac{a_t}{U_t} \right\} \dots \dots \dots (4a)$$

The error made by using this previously given formula for the sum of the weights of the tension and compression chord is but a small fraction of 1 per cent.

The average shear in the web is $\frac{L}{3}$ from the moving load of unity per foot of truss.

The average diagonal stress is $\frac{L}{6} \sec \beta$.

The average section of a tension web member is $\frac{L}{6} \frac{\sec \beta}{U_{t_1}}$;
that of a compression web member $\frac{L}{6} \frac{\sec \beta}{U_{c_1}}$.

The sum of the lengths of all tension or all compression members is $L \operatorname{cosec} \beta$.

The weight of the inclined web members is

$$\frac{\sec \beta \operatorname{cosec} \beta L^2}{6} \left(\frac{a_{c_1}}{U_{c_1}} + \frac{a_{t_1}}{U_{t_1}} \right) 3.4 = \frac{3.4 L^2}{3 \sin 2\beta} \left(\frac{a_{c_1}}{U_{c_1}} + \frac{a_{t_1}}{U_{t_1}} \right)$$

This does not include the vertical sub-posts and the vertical end posts. Allowing for these posts the formula becomes

$$W_{web} = \frac{4.25}{3 \sin 2\beta} \left\{ \frac{a_{c_1}}{U_{c_1}} + \frac{a_{t_1}}{U_{t_1}} \right\}$$

for unit moving load per truss.

The average value of U_{c_1} , must be taken to obtain approximately correct results.

If $B_i = \frac{4.25}{\sin 2\beta} \left(\frac{a_{c_1}}{U_{c_1}} + \frac{a_{t_1}}{U_{t_1}} \right) \dots\dots\dots (13)$

Then $W_{web} = B_i \frac{L^2}{3} \dots\dots\dots (13a)$

or the weight of the web is B_i multiplied by the shear area.

For the K system of web members we find in a similar manner

$$W_{web} = B_k \cdot \frac{L^2}{3} \dots\dots\dots (14a)$$

Where $B_k = 3.75 \left\{ \frac{a_{t_1}}{U_{t_1}} + \frac{a_{c_1}}{U_{c_1}} \right\} \left\{ \frac{1}{\sin 2\beta} + \frac{1}{2 \tan \beta} \right\} \dots\dots (14)$

The formula for the weight of the chords is the same as for the other web systems.

LATERAL SYSTEMS.

The two lateral systems are trusses with parallel chords and vertical end posts. The breadth B_r of the bridge is the height of the lateral trusses. The wind acts in both directions normal to the bridge. The wind stresses are, therefore all \pm . In the top

chords of the vertical trusses the compressions from the wind pressure are important; in the bottom chords the tensions. Each of the two chords of the top lateral system is at different times a compression chord. Those of the bottom lateral system are each at different times tension chords. From the formula for the weight of the chords of a truss with parallel chords we directly obtain the weight of the four chords of the two lateral systems for wind pressures p_w^c and p_w^t per foot of top and bottom lateral truss respectively.

$$W_{l.ch} = \frac{3 \cdot 4 l^3}{6 B_r} \cdot \left(\frac{a_c}{U_c} \cdot p_w^c + \frac{a_t}{U_t} \cdot p_w^t \right)$$

$$\text{If } A_l = \frac{3 \cdot 4}{B_r} \left(\frac{a_c}{U_c} \cdot p_w^c + \frac{a_t}{U_t} \cdot p_w^t \right)$$

$$\text{Then } W_{l.ch} = A_l \cdot \frac{L^3}{6}$$

Or the weight of the lateral chords is equal to A_l multiplied by twice the moment area for one direction of wind normal to the bridge.

LATERAL WEB MEMBERS.

For long spans the lateral diagonals are commonly compression members of box section consisting of four or eight angles latticed on four sides.

Double system inclined web members like Fig. 12 are commonly used.

FIG. 12.



If there are cross struts they belong to the cross bracing and will there be included. All members have equal and opposite stresses, but the two opposite maxima but seldom occur, and never in rapid succession. The sections are, therefore, commonly and properly determined by calculating the section required for each of the two opposite stresses and taking the larger section

thus obtained. To allow for surplus sections near the centre of the span, I shall assume, in the derivation of the formula for the weights of the web members, that the average shear from a unit wind pressure per foot is $\frac{L}{3}$. The average stress in the lateral diagonals is then $\frac{L}{6} \sec \beta$. The sum of the lengths of all the lateral diagonals of one system is $L \operatorname{cosec} \beta_l$. The weight of one system is then

$$3.4 \frac{L^2}{6} \cdot \frac{\sec \beta_l \cdot \operatorname{cosec} \beta_l}{U_l} \cdot \alpha_l = \frac{3.4 L^2 \alpha_l}{3 U_l \sin 2\beta_l}$$

and the weight of the diagonals of the two lateral systems to resist a total lateral pressure p_w per foot of bridge is

$$W_{ld} = \frac{6.8 p_w L^2 \alpha_l}{3 U_l \sin 2\beta_l}.$$

If

$$B_l = \frac{6.8 p_w \alpha_l}{U_l \sin 2\beta_l}$$

then

$$W_{ld} = B_l \frac{L^2}{3}$$

The total weight of the lateral systems inclusive of the lateral chords is, therefore,

$$W_l = W_{lch} + W_{ld}$$

$$W_l = \frac{3.4 L^3}{6 B_r} \left(\frac{\alpha_c p_w^c}{U_c} + \frac{\alpha_t p_w^t}{U_t} \right) + \frac{6.8 p_w L^2 \alpha_l}{3 U_l \sin 2\beta_l}$$

or

$$W_l = A_l \frac{L^3}{6} + B_l \frac{L^2}{3}$$

The cross bracing is introduced partly to carry the wind pressures down to the end shoes, partly to give to the posts of the vertical trusses intermediate supports to reduce their unsupported length. Its total weight, inclusive of struts, diagonals, and

chords, will vary considerably with different designers. A liberal system can be provided with a weight $W_{cb} = 2W_{ld}$.

DEAD LOAD STRESSES.

The steel required to carry the moving loads, wind pressures, and the floor must itself be carried. The weight of this is in an ordinary span fairly uniformly distributed over the length of the span. The stresses in the chords are the same as those due to an equal slowly moving load per foot of bridge. The formula (4a), therefore, applies without change, also, for dead loads.

The average shear due to a dead load equal unity per foot is $\frac{L}{4}$, while that due to an equal moving load is $\frac{L}{3}$.

The impact in the floor-beam hangers and the sub-posts and sub-diagonals is more than in the main members, and these members have, due to engine loads, much larger stresses from the actual moving load than from the uniform moving load which is equivalent for the chords. These excesses were allowed for in the coefficients for B. The web members required for a unit dead load weigh, therefore, only 0.7 as much as those for a unit of slowly moving load, and the weight of the whole truss is only 83 per cent. as large to carry a unit dead load as for a unit of a slowly-moving load.

Formulas (4a), (12a), (13a), and (14a) give the weight of steel in a truss to carry a unit of a slowly-moving load. The weight to carry the load $\mu = m_r(1 + I) + m_h$ is

$$W_\mu = \mu L^2 \left(\frac{AL}{12} + \frac{B}{3} \right) = L \left(\frac{A\mu L^2}{12} + \frac{B\mu L}{3} \right)$$

$$\text{If } C_\mu = \frac{AL}{12} + \frac{B}{3}, \text{ we have}$$

$W_\mu = \mu C_\mu L^2$ = total weight of truss required for the moving load stresses produced by the slowly-moving load μ .

The load μ per lineal foot of bridge replaces the actual rapidly-moving railroad load and its impact as well as the highway load.

$\omega_\mu = \mu C_\mu L$ is the weight per foot of bridge of the truss required for the moving load stresses of the load μ per foot of bridge.

The weight of steel in the trusses required to carry the dead load ω_μ per foot of bridge is $0.83 \omega_\mu C_\mu L^2$; and the corresponding weight per foot of bridge is $0.83 \omega_\mu C_\mu L$.

If $0.83 C_\mu = C_d$, then the weight of steel per foot of bridge required to carry the dead load ω_μ per foot is

$$\omega_\mu C_d L, \text{ or } \mu C_\mu C_d L^2 = \omega_d$$

The dead load ω_d per foot of bridge must also be carried. The weight of steel per foot in the trusses to carry it is

$$\omega_d C_d L = \mu C_\mu C_d^2 L^3$$

The total weight of steel per foot required to carry the moving load μ and the consequent dead loads is, therefore,

$$\omega_\mu + d = \mu C_\mu L \{1 + C_d L + (C_d L^2) + \dots\}$$

The infinite series in the bracket is convergent for $C_d L < 1$.

In this case its sum is $\frac{1}{1 - C_d L}$, and we obtain

$$\omega_\mu + d = \frac{\mu C_\mu L}{1 - C_d L}$$

and the total weight of the truss required for the moving load μ is

$$W_\mu + d = \frac{\mu C_\mu L^2}{1 - C_d L}$$

In this formula the numerator gives the total weight of steel in the trusses required to meet the moving-load stresses, and the whole fraction gives the weight of steel in the trusses for both the moving-load and the consequent dead-load stresses.

When the first load, like the weight of the floor, is a uniform dead load d per lineal foot of bridge, then the formula for the weight of the trusses to carry it is

$$W_d = \frac{d C_d L^2}{1 - C_d L} = \frac{D C_d L}{1 - C_d L}$$

where D is the total weight to be carried.

For spans over 200 feet curved top chords in through bridges and curved bottom chords in deck bridges are preferable, because considerably more economical. Empirical formulas for their weight have been given in the text of the paper.

APPENDIX B.

WEIGHTS OF CANTILEVER BRIDGES.

When the suspended span is separately erected and floated into position it weighs as much as an ordinary span of the same length and width.

Formulas for its weight have been previously given.

When it is erected by building out from the ends of the two cantilever arms it is built with parallel chords, and the bottom chords in all but the centre panels are made rigid compression members and the top chord splices are designed for tension. This calls for an increase of a_t and a_c .

Additional members are required above the end posts. The resulting increases in weight can be easily estimated and added to the weight of an ordinary independent span with parallel chords, and for long spans of exceptional width.

WEIGHTS OF CANTILEVER ARMS.

Assuming first parallel chords, we have for the moment from unit moving load per foot at the distance x from the end of the cantilever arm

$$M_x = \frac{l_s}{2} x + \frac{x^2}{2} = \frac{x (l_s + x)}{2}$$

The chord stress is $\frac{x (l_s + x)}{2h}$.

The weight of the chords of length dx is

$$dW_{ch} = \frac{3.4 x (l_s + x)}{2h} \left\{ \frac{a_t}{U_t} + \frac{a_c}{U_c} \right\} dx = AM_x dx$$

Where $A = \frac{3.4}{h} \left(\frac{a_t}{U_t} + \frac{a_c}{U_c} \right) \dots\dots\dots (4)$

The shear at the distance x from the end of the cantilever arm is $S_x = \frac{l_s}{2} + x$. The stress in the web diagonals is

$$\left(\frac{l_s}{2} + x \right) \sec \beta.$$

The area of the diagonals is

$$\frac{\left(\frac{l_s}{2} + x \right) \sec \beta}{U_{t_1}}.$$

The length of the diagonals with vertical posts in a length dx of the span is $dx \cdot \operatorname{cosec} \beta$.

The weight of the diagonals in a length dx of the span is

$$d \cdot W_d = \frac{3.4 \times 2 \left(\frac{l_s}{2} + x \right) \alpha_{t_1}}{U_{t_1} \sin 2\beta}$$

The vertical post stress is $\frac{l_s}{2} + x$

The post section $\frac{\frac{l_s}{2} + x}{U_{c_1}}$

The length of the posts in length dx is $\frac{dx}{\tan \beta}$

The weight of the posts in the length dx is

$$\frac{3.4 \left(\frac{l_s}{2} + x \right) \alpha_{c_1}}{U_{c_1} \tan \beta} \cdot dx$$

The weight of the web members in the length dx is

$$d \cdot W_{web} = \left(\frac{l_s}{2} + x \right) 4 \left\{ \frac{2 \alpha_{t_1}}{U_{t_1} \sin 2\beta} + \frac{\alpha_{c_1}}{U_{c_1} \tan \beta} \right\} dx$$

The increase of the coefficients from 3.4 to 4 covers the sub-posts and the sub-suspenders not previously considered.

Since $B_v = 4 \left(\frac{2 \alpha_{t_1}}{U_{t_1} \sin 2\beta} + \frac{\alpha_{c_1}}{U_{c_1} \tan \beta} \right) \dots \dots \dots (12)$

and $S_x = \frac{l_s}{2} + x$ we have

$$dW_{web} = B_v S_x dx$$

For a double system with inclined posts we obtain

$$dW_{web} = B_i S_x dx \text{ where}$$

$$B_i = \frac{4.25}{\sin 2\beta} \left\{ \frac{\propto t_1}{U_{t_1}} + \frac{\propto c_1}{U_{c_1}} \right\} \dots\dots\dots (13)$$

For the K system we have $dW_{web} = B_k S_x dx$ where

$$B_k = 3.75 \left\{ \frac{\propto t_1}{U_{t_1}} + \frac{\propto c_1}{U_{c_1}} \right\} \left\{ \frac{1}{\sin 2\beta} + \frac{1}{2 \tan \beta} \right\} \dots\dots\dots (14)$$

The weight of the trusses for a length dx and unit load per foot is

$$\begin{aligned} dW_I &= (AM_x + BS_x) dx \\ &= \left[A \frac{x(l_s + x)}{2} + B \left(x + \frac{l_s}{2} \right) \right] dx \\ W_I &= \int_{x=0}^{x=lc} dW_I = \frac{l_c}{12} \left\{ Al_c(2l_c + 3l_s) + 6B(l_c + l_s) \right\} \end{aligned}$$

W_I is the weight of steel in the cantilever arm required to meet the moving load stresses due to a unit load per lineal foot of bridge.

For a load μ per lineal foot of bridge we have for the weight of the trusses for the length dx

$$dW_\mu = \mu (AM_x + BS_x) dx$$

(To be continued.)

THE MAKING OF SOUND STEEL INGOTS.*

BY

BRADLEY STOUGHTON, Ph.B.,

Consulting Metallurgical Engineer, New York, N. Y.

THE metallurgist of to-day bears almost the same relation to steel as a doctor does to his patient. Where formerly a simple examination and a small number of tests completed a diagnosis, to-day the physician investigates the physical life history of the patient, together with some matters in the physical life of his parents and grandparents. The metallurgist also is not now content with the condition of the steel as revealed by mechanical and physical tests, but wants to be informed as to its life history during manufacture, and as to the quality of pig iron from which it was made and the conditions prevailing during the conversion and during the manufacture of the pig iron itself.

I believe that one of the greatest advances ever made in the manufacture of steel is the new system of inspection inaugurated under that great engineer and metallurgist, Robert W. Hunt, as described by him at recent gatherings of scientists.¹

It is comparatively easy to tell by the usual tests whether the structure and composition of steel attain a given standard or quality, but certain dangerous defects, which may be inherent in the metal, will often escape the customary inspection, and may be difficult to discover even by such extraordinary investigations as sulphur-prints, microscopic examination, hardness tests, shock tests, etc., unless these are carried on at such an extensive scale as to destroy the steel for service. Defects of this character are generally classified under the head of unsoundness, and the chief ones may be described as follows:

1. Presence of blow-holes;
2. Presence of combined and occluded oxides;

* Presented at the meeting of the Mining and Metallurgical Section held Thursday, October 30, 1913.

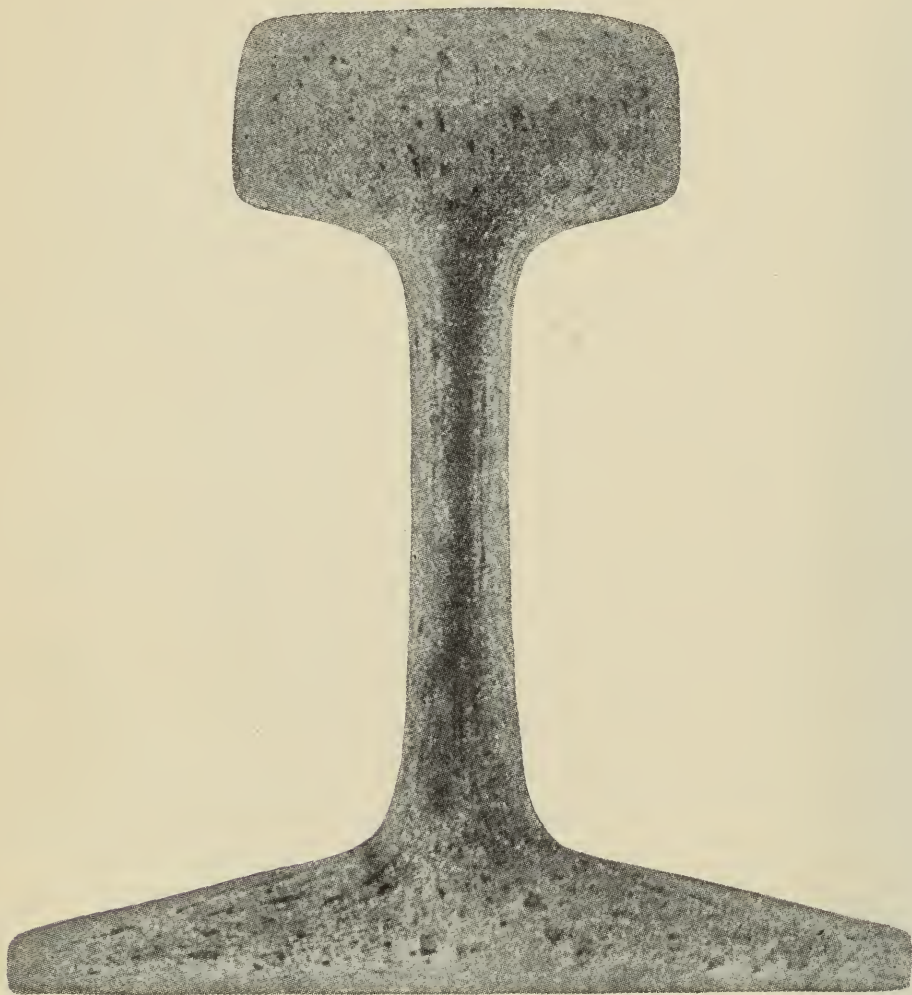
¹ Hunt: "Recent Developments in the Inspection of Steel Rails," Bulletin No. 72, A. I. M. E., December, 1912, pp. 1487-1495.

Hunt: "Comparative Notes on Steel Rail Rolling," Bulletin No. 77, A. I. M. E., May, 1913, pp. 879-883.

3. Presence of an unwelded shrinkage cavity; and
4. Excessive segregation.

The most effective means of preventing these elements of unsoundness is the exercise of great care and watchfulness during the manufacture of the steel, and also during the manufacture

FIG. 1.



Occluded oxide in steel.

of the iron from which the steel was made, because it now seems to be removed practically beyond controversy that certain unfavorable conditions during the smelting of iron ores in blast furnaces will produce a grade of pig iron which, during the ordinary process of manufacture, will be converted into an unsatisfactory grade of steel. It is not our purpose to discuss this matter at length in this paper, but the literature on cast iron

during the years 1913 and 1914 will afford ample proof of the accuracy of this statement. Fortunately, careful and expert inspection of the manufacturing process, and suitable testing of the product, are sufficient to prevent steel of this undesirable quality going into service.

Expert care and inspection during the manufacture and rolling of steel is also the best safeguard for preventing unsound metal from any of the other causes mentioned above going into the service of the consumer. Steel that is dangerously filled with blow-holes, or which is badly segregated, will give some indications of this condition during the ingot-forming or rolling stages. The presence of a residual unwelded shrinkage cavity can usually be prevented by proper inspection during cropping, although this is not an infallible safeguard. Oxide inclosures result from improper conditions of manufacture during the conversion of ingot-forming stages, such as: too late addition of ore to the open-hearth furnace; improper composition of the final open-hearth slag; insufficient fluidity of metal; wildness; excessive or improper addition of deoxidizers in the melt, etc.

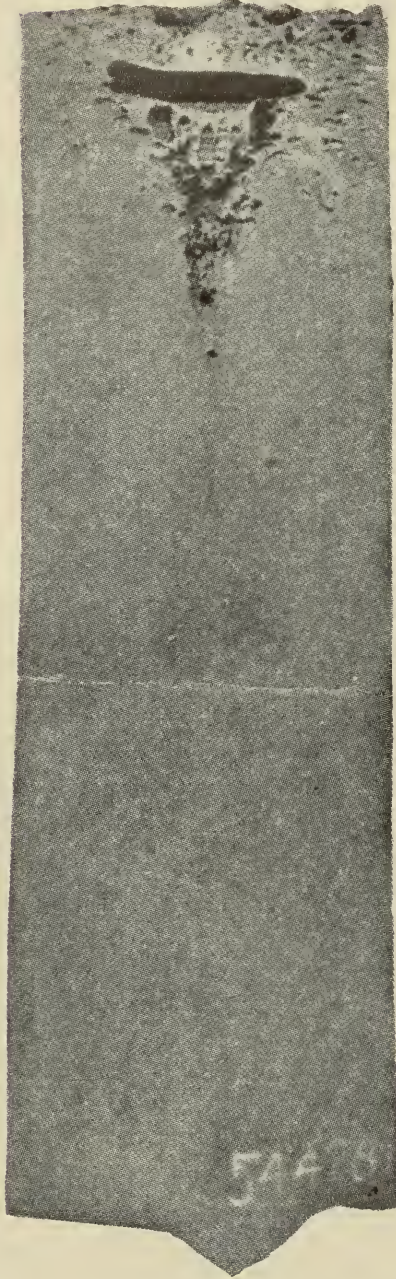
The subject of prevention of oxide inclusion has received a good deal of attention from several eminent investigators during the past two years, and a number of remedies have been suggested. The most effective means which has been extensively applied during manufacture is the addition to the liquid bath of steel of properly-proportioned quantities of titanium alloy.

Segregation does not occur to a dangerous extent when the phosphorus and sulphur are reduced to reasonable limits, provided the steel is properly deoxidized before teeming; is not wild in the moulds, and is poured in ingots not exceeding 5 to 10 tons each in weight. The larger the ingot, the smaller should be the proportion of sulphur and phosphorus in the steel, and ingots of very massive sections should not be used, unless the central core is to be drilled out and discarded, as is the case in the manufacture of large guns, for example.

The presence of blow-holes is not dangerous in low-carbon steels, except in certain situations, the causes for which are now well understood and can be eliminated. In medium and high carbon steel, the presence of blow-holes will always be indicated by the action of the liquid metal in the moulds, and suitable care in manufacture forbids such material going further in the manu-

facturing process. The careful steel-maker sends it at once to the scrap pile.

FIG. 2.



Shrinkage cavity in cut and split cold ingot.

The prevention or elimination of the shrinkage cavity in steel ingots and castings without prohibitive expense, or equally prohibitive complication in manufacture, has taxed to the utmost the

ingenuity of metallurgists, and many hundreds of thousands of dollars have been spent in experiments and investigations of

FIG. 3.

FIG. 4.



Ingot cast with big end down. Uniform thickness of ingot mould walls.

Ingot having same cross section at top and bottom and uniform thickness of mould walls.

numerous schemes and inventions. For many years the compression of the ingot during the process of solidification, in order to reduce the size of its outer envelope and thus compensate for

the shrinkage taking place during solidification, has been practised at steel works where steel of the highest quality is made. The

FIG. 5.

FIG. 6.



Ingot cast with big end up. Uniform thickness of mould walls.

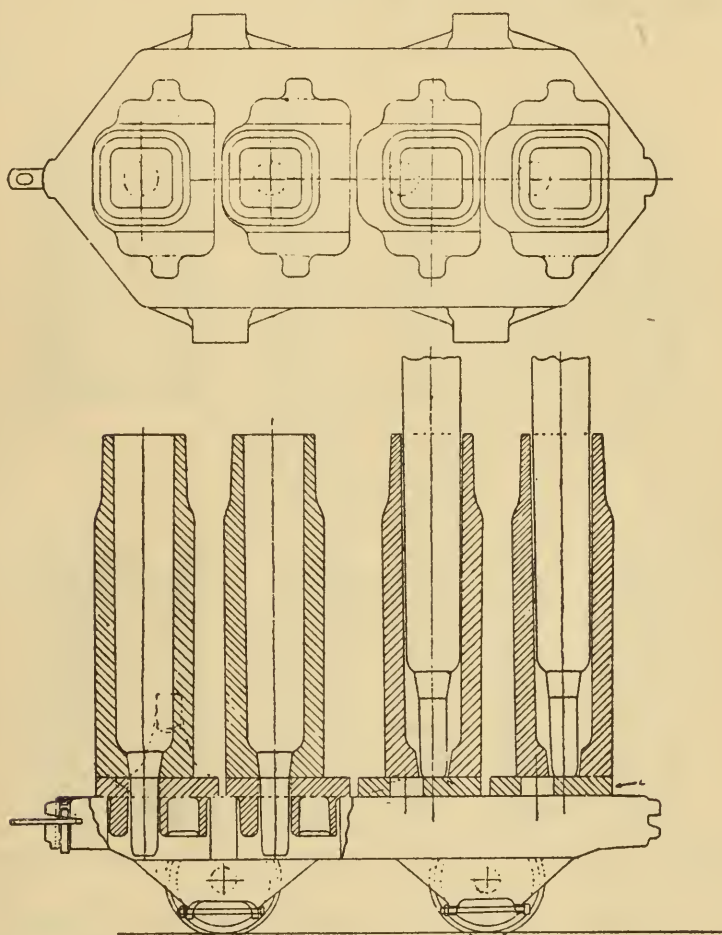
Ingot cast by Gathmann method, viz., big end up and thin mould walls at upper portion.

expense of this compression process, consisting of interest on investment, complication in the process of manufacture, and cost of operation, is not wholly compensated for by the lesser propor-

tions of the ingot which has to be converted into scrap. The compression during solidification is also claimed to improve the strength of the metal, and this claim, although not granted by all metallurgists, has some practical evidence in its favor.

An English and an American investigator have used the compression process for elimination of the pipe in a way which aims to eliminate interference with the manufacturing process and in-

FIG. 7.



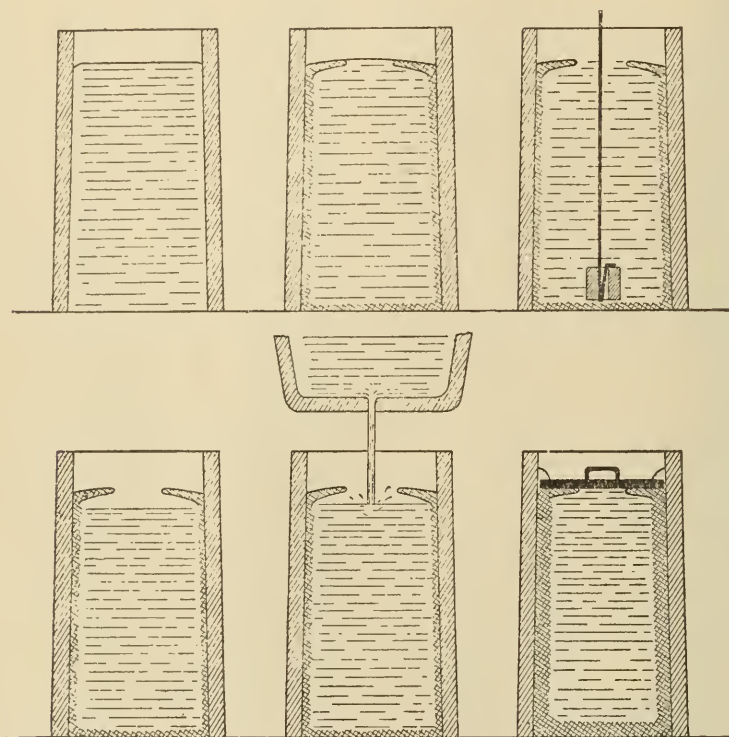
Gathmann ingot mould and stool.

terest on the investment, by taking the steel ingot before it has completely solidified and reducing its section in an ordinary pair of blooming rolls; then returning it to the heating furnace until entirely solidified, and subsequently completing the rolling operation in the usual way. Other recent investigators have aimed to accomplish a reduction in the cost of treating the steel by substi-

tuting some other method for the compression process, but none of these newer inventions secures the elimination of the shrinkage cavity, but only its reduction to a smaller size or a greater concentration at the top of the ingot, with consequent smaller proportion of cropped-off metal being necessitated.

Sir Robert Hadfield burns charcoal on top of the steel ingots in a special mould with a sand top, so as to delay the cooling of this portion of the metal and consequently draw the shrinkage cavity to that point.

FIG. 8.



Different stages in the treatment of steel ingots with anti-piping thermit.

Emil Gathmann, by a very ingenious method of casting ingots with the smaller end down and then stripping them without excessive inconvenience, as well as by distributing the metal in his ingot moulds, also produces a more rapid cooling of the lower parts of the ingot than of the top, and thereby concentrates the cavity in the upper portion.

The Goldschmidt process involves heating the metal in the top of the ingot by the well-known thermit reaction, or else by creating a stirring reaction in the ingot by means of a can of thermit,

through which, it is claimed, blow-holes, pipes, and segregation are all reduced.

Each of these cavity-reducing processes has been tried on a commercial scale long enough to prove its advantage under a given set of conditions. It is probable, however, that, in the production of very large quantities of steel, cropping off as much of the ingot as is necessary to remove the shrinkage cavity is cheaper than introducing a complication into the process of manufacture, and that careful inspection is an adequate safeguard for avoiding the dangerous defect in finished steel known as an unwelded pipe in the great majority of cases.

Alloys of Aluminum and Zinc. DR. W. ROSENHEIM and S. L. ARCHBUTT. (*Eng. Mag.*, xliii, 5, 772.)—It is widely recognized that an addition of zinc to aluminum facilitates the production of pure castings, though the zinc is said to cause the alloy to crack on cooling, and these alloys are liable to rapid corrosion. As to the corrosion, this was found to be due to impurities in the spelter, and was largely eliminated by the use of pure zinc. An alloy containing 25 per cent. of zinc could be rolled into bars and even drawn into wire. The addition of a small percentage of copper to these aluminum-zinc alloys greatly increases the tensile strength, while retaining a reasonable degree of ductility. Alloys containing from 15 to 20 per cent. of zinc are more serviceable than those containing less than 15 per cent. If dynamic as well as tensile tests are considered, the alloy containing 20 per cent. of zinc is the most generally useful of the simple binary alloys. All these alloys lose strength as the temperature rises, and cannot be forged at temperatures much above 400° C., and yet they exhibit an exceptional amount of ductility. There is a rapid fall in the yield stress and ultimate stress with rising temperature; even 50° C. produces a marked effect. Alloys containing from 10 to 30 per cent. of zinc can be worked by machine tools of all descriptions with great facility, and without the use of any lubricant in most cases.

The "Bakelite" Company. ANON. (*Metal Industry*, x, No. 9, 396.)—The General Bakelite Company has brought suits for infringement of the Bakelite patents against the Condensite Company of America, and several users of "condensite." The fundamental Bakelite patents have been allowed in Germany and have been sustained by the German Patent Office, notwithstanding that there were several public contestants.

The Volatile Constituents of Coal. A. H. CLARK and R. V. WHEELER. (*Chem. Soc. Trans.*, ciii, 1704.)—The results of further experiments support the view already advanced that coal is essentially a conglomerate of (1) degradation products of celluloses, and (2) partly-changed resins and gums of the plants from which the coal was derived. The former yield hydrogen and the latter paraffins as the main gaseous products of thermal decomposition. Pyridine effects only a partial separation of the two constituents. The pyridine extract slowly yields about one-third of its weight to chloroform or benzene when treated therewith in a Soxhlet extractor. The substance removed is a sepia-colored solid, which softens at 90° C. and partially melts at 102° C. It contains 80 per cent. of volatile matter, and on destructive distillation yields 43 to 64.5 per cent. of tar (chiefly paraffin hydrocarbons), together with gases consisting mainly of paraffin hydrocarbons and hydrogen. The portion of the pyridine extract insoluble in chloroform is similar in its properties to the portion of the original coal insoluble in pyridine, and it is considered that extraction with pyridine, followed by extraction of the pyridine extract with chloroform, will effect a complete or nearly complete separation of the resinous constituents from the degradation products of the celluloses. Russell has shown that rosin has an action on the photographic plate in the dark, and that coals have a similar action at about 50° C. It is now shown that, while the portion of coal insoluble in pyridine and the portion of the pyridine extract insoluble in chloroform have no perceptible action on a photographic plate, the total pyridine extract produces a distinct image, and the portion of the pyridine extract soluble in chloroform produces a strongly-marked image surrounded by an extensive halo.

Utilization of Coal Dust from Locomotive Smoke-Boxes. ANON. (*Eng.*, xcvi, No. 2488, 335.)—The two railway stations, Ostrowo and Skalmierzyce, which are about eleven miles apart from one another, are supplied with electricity for light and power from a power station at Ostrowo, in Prussian Silesia. The Skalmierzyce station is on the Russian frontier. The interest lies in the fact that the fuel utilized is the fuel dust which is carried through the tubes of the locomotives and collects in the smoke-boxes. This fuel is placed in gas producers to feed suction-gas engines. Similar plants have been in use for some time near Königsberg, in Prussia. Two gas engines are installed, each of 180 horsepower, and drive two dynamos, which are independent of one another, one for each station. Current is generated at 5000 volts three-phase, and transmitted at this pressure to the Skalmierzyce station. For the Ostrowo station the current is transformed into continuous current of 230 volts. The dynamos and main conductors are provided in duplicate. Such plants are hardly likely to come into general use, but the application is interesting and may be of value in special cases.

THE FREIBERGER PROCESS OF DISCHARGING COTTON PRINTS.*

BY

ERNEST STÜTZ,

Member of the Institute.

THE art of dyeing and printing cotton fabrics has participated with all other industrial development of the last fifty years in the tendency to substitute chemical reactions for mechanical processes. The old natural dyes used more or less since the infancy of the human race have been abandoned in favor of products resulting from chemical synthesis, and the slow and cumbersome, if durable, methods of applying them to the fibre had to give way before the need of greatly accelerated and varied output. The one branch of this art which I desire to speak of here deals with the production of decorative effects by the removal of the color from the dyed, particularly indigo-dyed, fabrics by means of chemical reagents, thereby producing a pattern. This procedure, in French and German perhaps more plainly described by the equivalent of the word "etching," is known in English as "discharging." The ground color is removed where the discharge color is applied, and wherever this occurs the fabric recovers its original white tint.

In earlier days this pattern effect on the goods was generally produced by printing a so-called reserve or resist color on the undyed white material so that in the subsequent immersion of the entire fabric in the dyeing vat only the portions not printed on with the reserve showed the vat color. The reserve disappeared in the washing operation which followed, and the pattern then showed up. This method is retained to the present day in some works for certain purposes. For standard manufacture on a large scale it has been replaced by the simpler and more productive methods of discharging, the reagents used being either chromic acid (first used by Koechlin), sodium chlorate, or, in some cases, bromate. Recently the sulfoxylate method has also been pushed to the front very energetically.

* Based on a paper by M. Freiburger, *Färber-Zeitung*, vol. 24, 1913, parts 1 and 2, and communicated by the author.

Mr. Freiburger conceived the apparently very bold idea of using nitrates or nitrites as being not only very effective but also most economical discharging agents. The first attempts at putting his idea into practice were very disappointing, but, after a thorough study of all the problems entering into the question, a most efficacious and successful method was devised and brought to full industrial development, so that at the present time the nitrate process is carried out with uniformly excellent results in the largest European establishment for blue as well as calico printing.

The Freiburger method passes the cotton fabric imprinted with nitrate discharging color through hot and concentrated sulphuric acid, and by accurate control of strength, temperature, and time exposure not only preserves the fabric in its undiminished strength, but obtains the most accurate and permanent discharge effects.

A print color consisting of nitrate dissolved in starch paste does not, as is well known, discharge indigo on dyed material in dilute hot sulphuric acid, although, without a doubt, the anions NO_3 and NO_2 respectively are liberated in this case. Nitrous sulphuric acid, a solution of nitrogen oxides in concentrated sulphuric acid, for instance nitrosulphonic acid (nitrosyl sulphuric acid cryst.), $\text{NO}_2\text{--SO}_3\text{H}$, discolors indigo by oxidation. Beyond isatin there are said to have been shown as final products of oxidation nitrosalicylic acid, picric acid, and even oxalic and carbonic acid. These oxidation products are easily soluble in water or alkaline solutions, as, for instance, in dilute caustic soda, silicate, or soap.

First it was necessary, in the manufacture of such nitrate discharge products, to obtain conditions similar to those which prevail in the lead chambers of industrial sulphuric acid manufacture,—that is, the simultaneous presence of (1) nitrous gases, viz., nitric acid and reducing agent (there sulphurous acid) or nitrous acid (from nitrite), (2) heat, and (3) an acid of about the concentration of chamber acid. The thickeners used in the printing of nitrate colors, usually starch, already carry a substance into the sulphuric acid which acts as a developer in the discharging vat and quickly brings the free nitric acid to a lower stage of oxidation, which effect is further increased by the intentional addition of other reducing agents.

More difficult of solution was the problem of safeguarding the strength of the fibre. A cold acid of 49.5° Bé. (104° Tw.) mercerizes the cellulose about as much as concentrated caustic soda (patent application Thomas Prevost). A stronger acid produces a parchment effect by the formation of a layer of hydro-cellulose and amyloid. Still stronger hot sulphuric acid carbonizes the cellulose on longer exposure, owing to water extraction. According to Schwalbe, cold acid of 40° Bé. (77° Tw.) has a weakening effect only after twenty hours, and if of 46° (94° Tw.) only after some hours, or if mixed with an equal volume of water (that is of about 65 per cent.) it has, according to Koechlin, at 46° (94° Tw.) an effect on the cellulose only after one hour. It was proved by experiments that between the limits of 36° and 45° Bé. (67 – 91° Tw.) good discharge effects are obtained.

According to the results of these observations the formulas were worked out which give the proper combination of monohydrate content, temperature, and time of exposure on which the success of the operation depends. The results have also been checked by numerous tensile tests. Among others, tests made at the mechanico-technical laboratory of the Technical University of Vienna in comparing nitrate discharged fabric with others treated with the best oxidation method (steaming process) gave, on divided pieces, the result that the nitrate material in one case was 5 per cent., in the other even beyond that percentage, stronger than the undischarged parts of the material.

In the case of an acid of 42° (82° Tw.) at 65° C. (149° F.), with two seconds' immersion, the print color is not fully utilized for the discharge (or, in other words, a longer discharging passage would produce a stronger discharging effect), so that a part of the nitrous acid dissolves in the discharging vat. For this reason, to protect the indigo ground it was necessary to neutralize the unused excess of nitrous combinations. In the beginning nitrous acid was supplied in the form of an addition of bisulphite. Sulphurous acid being hard to dissolve in warm sulphuric acid, organic substances, such as potato starch, were used in order to supplement the reducing effects, and, later on, cheaper materials, such as woodflock and rags. This combination fully preserves the beauty of the indigo ground, while the undischarged parts in no way suffer from the acid.

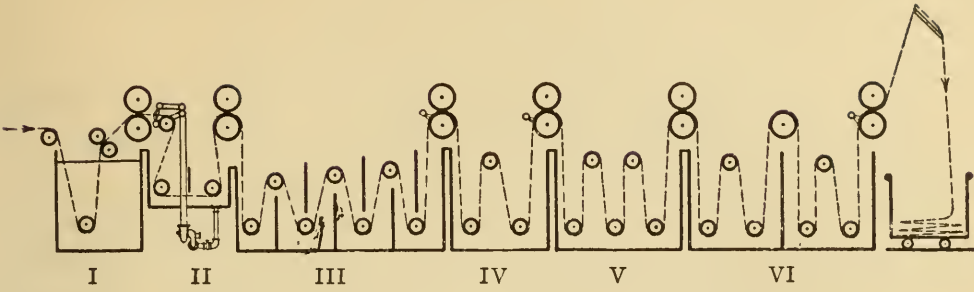
What takes place in the discharging vat may be assumed to

be a tendency of the fabric, on coming into sudden contact with the hot concentrated acid, to stiffen as in mercerization. Similarly, pieces with Prud'homme black coming out of the Mather-Platt agar are harder to the touch and also more brittle until they are washed,—that is, until the neutral reaction takes place. So long as the cotton fibre shows acid reaction it is more liable to break than in a condition of neutral reaction. This experience can be made any day in bleaching, and even a bichromate solution makes cotton more tender. A similar phenomenon may be observed when printing with a strong color containing caustic alkali, such as, for instance, Schlieper & Baum indigo color. The material appears to have lost strength. However, on thoroughly washing such printed goods the old strength not only reappears, but in many cases is increased. The same occurs in nitrate discharging. The fabric, after washing and neutralizing in dilute lukewarm alkali, shows a strength at least equal to that which it had originally.

The mechanical arrangements of the Freiburger process provide in the first vat (containing the sulphuric acid) one lower guide roller running on slide-rod bearings so as to simplify raising and lowering. Care must be taken to have this accurately adjusted in its horizontal and parallel relation to the other guiding elements. The material is drawn in either with a copper wire or a cord. With a little adroitness the operation is quickly and steadily performed, without danger of injury to the workmen. Altogether so far this discharge process has not in any single instance been the cause of injury to workmen. Once started, the apparatus runs all day quietly and evenly. In case of accidental stoppages, for instance, due to interference in the power supply, only the material in the first tank to the extent of about two yards has to be removed. The ends can be drawn in again in a few minutes. The efficiency of the machine is such that these interruptions are negligible. The length of the immersed piece, between acid surface and squeezing rolls, is about 2 to $2\frac{1}{2}$ metres (about $2\frac{1}{2}$ to 3 yards). Allowing 2 to $2\frac{1}{2}$ seconds for the passage, the apparatus gives a speed of one metre per second, or 36,000 metres (about 40,000 yards) per ten-hour day, which is sufficient for most European works. Two workmen can run the machine, with one additional helper to start it up.

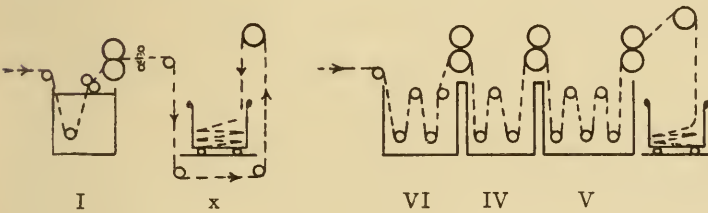
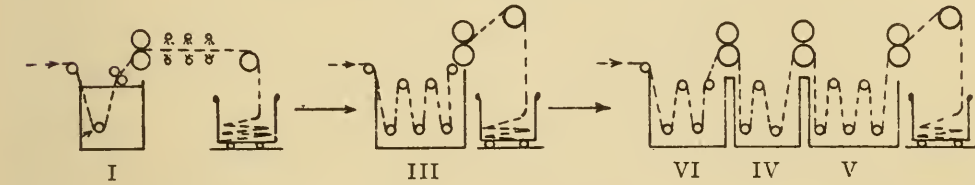
After passing the acid tank, the material is run through the

FIG. I.

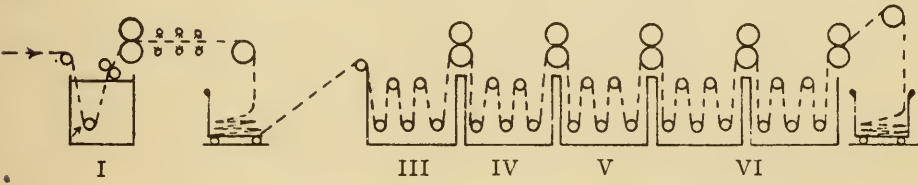
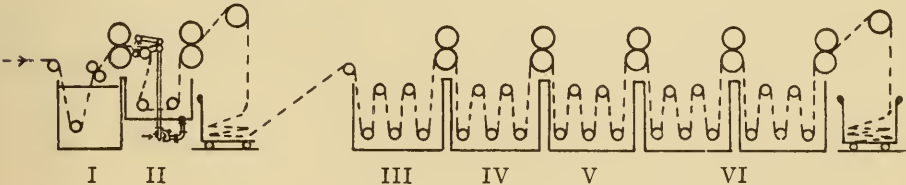
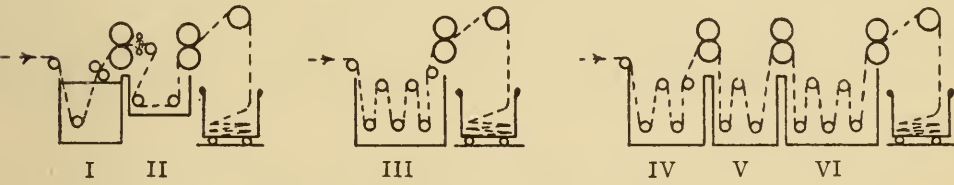


Standard apparatus for Freiberg's nitrate discharge.

I. Development bath. II and III. Regeneration and rinsing compartments.
IV. Washing compartment. V. Dilute lye. VI. Water,



At x pass through running water.



Modifications of standard apparatus.

squeezing rollers, ordinary acid proof rolls, the lower being coated with hard rubber or lead and the upper being a rubber roll. These must be washed with water at the end of operations in order to keep clean and smooth; otherwise the acid would run together in spots and the rubber would crumble away gradually. Of course pieces must be stitched together, not tied.

Taking advantage of the great speed of the machine, it was found useful to arrange for two small lead rolls in front of the squeezing rolls proper. They are carried along by the material and relieve the big squeezers of an appreciable part of their work. The advantage is twofold. At high speed the squeezing impact is in the nature of a blow. This is now avoided. Furthermore, the tendency of the softened print color to run away under the spraying effect of the acid running in a direction opposite to that of the goods is overcome by the pre-squeezers, as they are placed immediately above the line where the piece emerges from the acid. Passing through the pre-squeezers, the piece runs at an easy angle upward, toward the large squeezers at the end of the tank, thereby preventing the formation of lakes or tongues. A considerable tractive effort is required to move the pre-squeezers, although they run in roller bearings, but, nevertheless, thin materials like light cambrics pass through them without injury. This clearly proves that the passage through the acid has not the deleterious results that had been anticipated, and, as a matter of fact, in a properly-constructed apparatus the passage of the goods need cause no apprehension whatever.

As soon as the material leaves the first compartment it undergoes rapid and thorough cooling; for this purpose two perforated pipes are provided directly back of the squeezing rolls, whence the material is sprayed from above and from below with dilute cold acid taken from the washing vat. In the beginning the importance of cooling from both sides was disregarded, although by touching the lower side of the fabric it could be at once perceived that it remained hot in spite of spraying from above. Apparently the material at this stage is less permeable to fluids, but improves in that respect upon reaching the next tank. A heating during spraying on account of dilution of acid is not to be apprehended, as sulphuric acid of 42° Bé. (82° Tw.) is capable of dilution without development of heat. The two spray

pipes are best provided with a separate cock each, which, after a preliminary trial before beginning work, are set once for all. This avoids waste of water and too great a dilution of the acid, the recovery of which is of economical importance.

The passage through the different compartments is regulated by the circumferential speed of the delivery rolls in accordance with requirements.

It may be assumed that 1 kilogramme (2.2 pounds) material carries along with it 800 to 900 cubic centimetres (50 to 55 cubic inches) acid from the discharging vat. By means of a small lead-lined rotary pump, installed close to and below the first rinsing trough, this is made to undergo circulation in the manner customary in diluting the lye in mercerization. What acid remains is sprayed off later by counter-current. For spraying and cooling of the discharged material the more dilute acid from the later compartments is used, so that the concentration of the recovered acid may be set at between 9° and 18° Bé. (14–30° Tw.) as required.

In the next two compartments (III and IV) the fabric is entirely freed from acid; the application of the principle of rinsing by counter-current has here given good success. Partitions are placed in the washing vat, which alternately reach from the bottom upward to nearly the level of the liquid, or from the surface downward to nearly the bottom of the tank. Two tanks, together of a length of about 4 yards, are sufficient under all circumstances.

In this passage confirmation may be found for the observation that interior strains from the acid passage are released after washing, and that as soon as the cotton enters the alkaline bath it regains its full suppleness and softness. Besides, in this case the disparity of strains is not nearly so great as in mercerization.

The acid drawn from the wash tanks can without difficulty be conveyed directly to the places where it is used, and the most efficient arrangement would provide for simultaneous operation of the discharging apparatus and the other processes using the acid. For instance, in a works where production sometimes reaches 20,000 metres (21,880 yards) a day a reservoir of a capacity of 1800 litres (63 cubic feet) was found sufficient for the temporary storage of the acid at about 9° Bé. (14° Tw.).

A small phosphor bronze injector easily distributes the acid from the reservoir to the various places of consumption.

The most obvious application of the used acid is for purposes of dilution of the technical concentrated acid to the degree proper for this process. This is done in a tank placed above the feeding reservoir, in order to have a continuous automatic flow of the acid supply. By this means one-quarter to one-third of the used acid can at once be brought back to the discharging apparatus.

The acid supply, by means of lead coils, is brought to the same temperature as the acid in the first tank. These pipe coils which run directly from the diluting tank to the cutting vat are also connected with the water system in order to allow of easy and quick regulation of the temperature. The strong recovered acid is of a faintly bluish color; it contains traces of indigo, which in the course of operations appear on the surface of the acid bath, being that portion which only loosely adheres to the fabric. The dilute acid contains also small quantities of organic matter, and of nitrogen-oxygen combinations. In the dilution of about 1° Tw. it is clear as water; it is very useful in the souring of indigo resists and of plain vat-dyed materials. The recovered acid is either diluted as required, or the regeneration process is set definitely at a fixed degree.

Practical experience has shown that the recovered acid can readily be utilized for all purposes in bleaching. It has been used for non-mercerized as well as mercerized, fine as well as heavy goods, before bowking or after chloring. The goods treated with this acid were afterward finished with the most tender uniball colors, or even plain white, or could be printed with steam colors, such as alizarin rose, light blue, or light yellow, without the slightest inconvenience.

The recovered acid is equally applicable to the souring, after soda-lye treatment, of mercerized white goods.

The preference to be given to one or the other of these methods of reusing the acid depends on local conditions.

An examination of the material as it comes out of the wash tank shows that it barely gives an acid reaction. The acid has been almost entirely retained in the two washing compartments. A calculation, based on color consumption per piece and quantity of saltpetre contained in the color, of the equivalent of free acid lost through combination with soda, will show a loss, according

to pattern and material, of from 2 to 5 per cent. of the total acid used.

In a good apparatus a recovery of over 90 per cent. of the sulphuric acid may be counted upon. If the manufacturer employs the acid first for discharging purposes, instead of sending it directly to the other consuming departments, the cost of the discharging operation, and thereby the cost of the entire process, will be very low indeed. The cost of the latter is composed of print color, lost acid, wages, and steam consumption for heating the acid, as well as motive power for the discharging apparatus. From the point of view of economy, the most efficient layout will be to provide each day that number of pieces for discharging which will be proportionate to the requirements of acid for other purposes. Should this be impracticable, it may occur that part of the recovered acid is lost. In the most unfavorable case, where the entire acid (except that part which is used to grade the supply or to dilute the fresh acid) would be lost, the cost of the development bath will still be much lower than the oxalic acid-sulphuric acid baths. This is true even in the case where the latter is diluted and is used of a low oxalic acid strength, and, as is also frequently the case, where expensive chromate color is wasted in its place. Incidentally such solutions weak in oxalic acid may be cheaper, but they give inferior results.

The method of thickening the print color has a bearing on the development of the discharge. Starch and its products, the soluble starches, give the best results; for instance, starch disintegrated to the consistency of gum by means of acetic or formic acid. Nitrate of soda gives to the starch a clear, gum-like appearance. An addition of sulphate of barium in paste form, even to the extent of a proportion of 1 : 1, is advisable, or, in the case of fine patterns, flour, tragacanth, or some leogommes. A mechanical action can be ascribed to the baryta paste, as it improves the covering white, acting as a sort of accumulator for the retention of the nitrous gases and partly preventing their premature escape by absorption. It also improves the neatness of the design, because the color is more nicely cut by the edges of the engraved lines, so that the imprint stands out better. The white paste has the additional advantage that the pattern shows up on the blue ground at the printing machine, and supervision is made easier. Part of the baryta paste is dissolved by the sulphuric acid, and

another part drops off in the subsequent washing. The remainder—and that quite an appreciable quantity—fixes itself upon the discharged white places.

The white, above all things, must be pure and clear, free from traces of undischarged blue, and standing out well from the blue ground without any bluish tinge. For the optical effect of the white it is desirable that the foundation, if possible, should not be blue but white,—that is, that the print color should penetrate and permeate as deeply as possible into the core of the fibre. With shallow or badly penetrating colors the blue ground shows through and gives to the reflected rays of light a bluish tinge. On the other hand, if a white surface is obtained by merely pasting on a white pigment, such white is not fast, as already the first washing makes it appear bluish and dirty. Nitrate white has the advantage of being pure white without any bluish tinge. A deep penetration of the color into the fibre can be easily obtained by making the consistency of the color more gummy by extensive dextrination of the starch. By contrast of the pure untinged white with the blue foundation the latter appears very bright.

For the alkaline bath (V) which follows the rinsing troughs, dilute caustic soda, or silicate, or soda may be employed. The alkali removes, on the one hand, the products of reaction from the white parts, and, on the other hand, from the indigo ground the yellow tinge it had gotten in the acid compartment, so that the indigo emerges from the treatment without any loss, undimmed and clear. The bath has now taken a light-yellow shade. The final blue of the fabric is very fine and bright and can be equalled only in the bromate process. The indigo has a from 6 to 10 per cent. stronger color effect than with other well-known methods.

In the chlorate discharging process the alkali passage makes the indigo ground paler and duller, even if a slight preliminary washing operation precedes the steaming, because in that case the alkali is charged with chlorine-oxygen combinations, while in the Freiburger process there is no danger of the indigo being injured through the alkaline solutions of nitrogen-oxygen combinations. Further, it is well known that alkaline passages have a deleterious effect if they contain a lye of excessive strength or reducing agents like hydrosulphite.

The following is a description of the process as applied to a simple example of white discharge. It is immaterial whether the goods have been dyed in concentrated or dilute, dipping vats or skying machines, or in both, whether with many or few passages, whether in light or deepest indigo shades, whether non-mercerized or mercerized, on one or both sides. The nitrates being very soluble in water, the discharging of the very finest pin-points offers no difficulty, even with the deepest and fastest dyes, and an excess of discharging agent may be dissolved in the color. After printing, the piece passes through a box with drying machine attached, from which it emerges ready dried.

Discharge White for Deep Indigo.—One ounce corn starch, $\frac{1}{2}$ ounce wheaten flour, 11 ounces water, 0.12 ounce oil are boiled together; after cutting off steam, dissolve 8 ounces nitrate of soda and, at 86° F., add 10 ounces sulphate of barium paste. Make up to 2 pounds weight. Crude saltpetre used for fertilizer purposes can be employed, which is dissolved in water, filtered, and perhaps cut with a little acid before mixing and boiling with starch. As paste a wheat starch thickener is used, containing flour, tragacanth, protamol, or slightly-roasted starch, or the following: 3 ounces corn starch, 3 ounces tapioca flour, $2\frac{1}{2}$ ounces acetic acid 9° Tw., $\frac{1}{2}$ ounce oil, 23 ounces water; boil up to 176° F., hold at this temperature for 10 to 15 minutes, then cool and make up to 2 pounds weight. Sulphate of baryta paste may be added in the proportion of 1:1. Printing had best be done with the addition of the sulphate of baryta paste, the above-mentioned strong color being diluted with paste in the proportion of 20 to 50 per cent. for heavy dark blue, 50 to 100 per cent. for medium blue, and even more for cadets. To always obtain reliable results it is best to work with two standard colors, one for fine materials and one for heavy goods, containing 20 or 40 per cent. paste.

Development after Printing.—The printed pieces are passed for two or three seconds through the cutting vat containing sulphuric acid at 42° Bé. (82° Tw.). This is lead lined and heated indirectly by means of lead coils. Behind this follows a second compartment where the acid is recovered from the goods by spraying the wash water against them. A third compartment serves to clean the discharged parts and to neutralize the acid residue still clinging to the fabric. This is followed by a water

rinser, and in connection with it a squeezer and drier. The goods pass the machine without interruption from morning until night, the acid of the required strength being automatically renewed. The acid is never let out of the discharge trough, and is constantly ready for further use. Fig. 1 shows an apparatus of standard construction, which may be simplified as per Fig. 2 in order to utilize some already existing machinery.

The color prints with a simple pattern roller all day long without attacking the pressure drum or doctor blades or clogging the pattern. Other print colors cover the ground with fine blade scratches, and these are visible only after steaming, but in the finished piece the ground has then a disturbed appearance or the blue comes out pale and faint. The nitrate colors do not attack either the goods or the back cloth and can be kept for weeks without spoiling.

The print color is very cheap. One kilogramme (2.2 pounds) costs for deep indigo 12 pfennig (3 cents), for medium blue 9 pfennig (2 cents), and for light blue $6\frac{1}{2}$ pfennig ($1\frac{1}{2}$ cents). Printed goods and printed back cloths can await discharging operation indefinitely. Hence there is no objection to using new goods for back cloths; they do not suffer either at the edges or in the centre. Printed goods can be kept in any manufacturing part of the building. Where a dry room is not available, nitrate of potash may be used in place of nitrate of soda with good success. In case of errors in printing, washing in water will clean the goods and they can be printed over again.

The white discharged places remain unchanged during storage and uniformly white; they contain no trace of either oxy- or hydro- or hydrated cellulose, which was proved by the well-known tests on several samples having a white discharge several centimetres wide.

Such white discharged goods are suitable to be printed over and for coloring of alumina mordants with alizarin red as well as printing with basic colors.

The method facilitates production on a large scale. Owing to the particular printability of the colors, printing can be regulated to proceed as quickly as the machine can operate. The acid tank, on account of the short distance the goods have to travel in it, can be made to conform to the greatest speed of any cloth washer,—for instance, a capacity of 36,000 metres (40,000

yards) or more per ten-hour day. Half an hour after printing, the goods are already fit for finishing. This gives the advantage to the printer that, while yet printing, he can see the goods fully developed.

The running of the machine does not create the idea of danger in the minds of practical men. Failure is no more to be feared if directions are properly followed, and normal supervision, such as is entrusted to any reliable workman, is exercised, than in passing cotton through fire in singeing or exposing it to caustic soda solutions under pressure during bowking. Every supply tank of acid is checked once with the hydrometer, and in most works this is done only once a day, before commencing operations. It has been shown by experience that the temperature can be maintained without difficulty during several hours' operation, as a supply of 1500 litres (396 gallons) in the tank and supply holders is sufficient for a full day's production.

The supervision consists of preparing the acid just as in chromate and regulating the temperature before and during operations. Inferior goods cannot be produced, as in case of improper operation or carelessness the apparatus will not work. The passage is therefore automatically regulated and checked.

As compared to other processes, the cost on medium blue, based on actual European working figures in large establishments, taking nitrate at 100 per cent., is for chromate 242 per cent. more, for chlorate 308 per cent. more, for bromate 706 per cent. more, or, even if all acid, except that serving to dilute the technical acid to 42° Bé. (82° Tw.), is lost, 70 per cent., 105 per cent., and 300 per cent. more.

For dark indigo stronger and therefore more expensive discharge colors are used, or, in the case of chromate, more expensive discharge baths. In this case, taking again nitrate at 100 per cent., chromate costs 229 per cent. more, or, in case of loss of the sulphuric acid, 127 per cent. more.

The economical results of the new method justify its introduction in small as well as large works. The saving will soon pay for the cost of installation. The product will compare very well, as regards appearance, quality, and uniformity, with those of any other method now in use, whether discharge or resist. Particular attention may be called to its uniformity, as in that respect most processes are deficient and it is an important point

with the buyer. The adherents of the reduction method like to insist on the presumed danger from the acid passage. It was in order to refute these apprehensions by the results of several years' practical and successful operation that the inventor postponed giving his process the wider publicity it deserved.*

In order to investigate possible changes of the cotton into oxy- or hydrocellulose in a practical manner, a large quantity of the worst and earliest experimental pieces from the year 1909 were made into dresses and blouses. After much laundering and constant wear these are to-day,—that is after three years,—in good and fit condition. After such tests, and considering that by now more than 10,000,000 yards have been discharged with nitrate, this process may safely be taken up by manufacturing plants as a tried and approved method.

* Previous references: Dr. Franz Erban, "Entwicklung der Oxydations Ätzen in der Blaudruckerei," *Chemiker Zeitung*, No. 67, 1910. M. Felix Binder, "Rongage de l'Indigo à l'aide des composés oxygénés de l'azote," *Bulletin Annuel de l'Ass. Gén. des Chimistes de l'Industrie Textile*, Paris, 1911.

Influence of Drilling Holes on the Strength of Soft Steels. ANON. (*Amer. Mach.*, xxxix, No. 14, 555.)—Tests made at the École Centrale, Paris, are reported in "Le Génie Civil" to show that when holes are drilled and then reamed in soft-steel bars the metal materially increases in strength, the average limit of elasticity improving 12.3 per cent. and the average tensile strength 9.2 per cent. This phenomenon is explained thus: In putting together the parts of a test piece broken under tension, it is found that the two ends do not coincide; and that, while the edges make a good contact, the central parts do not, thus indicating that the rupture begins at the centre, and that the edges have a higher tensile resistance than there is along the axis of the bar. Therefore, if several holes are drilled so as not to injure the material too much, as might be the case with punching, the average tensile strength of the section across the holes, per unit of metal, will be higher than before the holes were drilled, since each hole creates, so to speak, additional edges.

Action of Finely-Divided Nickel on Nitric Oxide. R. S. FEGATE. (*Chem. News*, cviii, 178.)—Nitric oxide was circulated through hot water containing in suspension finely-divided nickel, prepared by reducing the dry precipitated hydroxide by hydrogen. The nickel was rapidly oxidized and nitrogen was formed. Colloidal nickel prepared by Bredig's method of electrical disintegration failed to produce a similar result.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NOTE ON THE SETTING OF A MERCURY SURFACE TO A REQUIRED HEIGHT.

By M. H. Stillman.

(From Bulletin of the Bureau of Standards.)

A COMMONLY-EMPLOYED method of setting the mercury surface in the cistern of a barometer of the Fortin type is to raise the mercury surface relative to the downward-projecting ivory pointer until the end of this pointer makes a minute dimple in the surface. It has been found that the setting can be made more easily and with much greater precision by placing on the side of the cistern opposite to the observer a scale consisting of alternate horizontal black and white lines, each line being about 0.5 mm. wide, so that the image of this scale may be seen in the mercury surface at the place where the contact will occur. Before contact occurs the lines of the image are practically uniform in width and parallel; but as soon as a very minute dimple is formed the fact is made known by the distortion of the lines of the image in the immediate vicinity of the point of contact. The fact that the distorted part of the image is surrounded by an undistorted field of parallel black and white lines of uniform width makes the distortion very easy to detect.

Experiments were made to determine with what precision settings of a mercury surface could be reproduced by this method. In a sample set of five consecutive readings the greatest deviation from the mean was 0.0007 mm., while the average deviation from the mean was 0.0003 mm. Even closer agreement of settings was obtained when the illumination and the condition of the observer's eyes were more favorable.

The accuracy with which settings could ordinarily be reproduced by using the method of noting the apparent coincidence of the end of the pointer and its image was also investigated and

* Communicated by the Bureau.

found to be less than by using the improved method just described.

The mercury surface, when set by the ordinary dimple method, is higher relative to the pointer than when set by noting the apparent coincidence of the end of the pointer and its image. The improved dimple method gives a setting between those given by the ordinary dimple method and the method making use of the apparent coincidence of the end of the pointer and its image. In ordinary barometry the differences in settings by the various methods are generally negligible, but in very precise work they should be considered.

The improved method should be especially valuable where it can be applied to reading both ends of a mercury column; for when used in this way the constant errors of the settings cancel, thus allowing the great sensibility of the method to be realized.

THE VISCOSITY OF PORCELAINS.

Technologic Paper by A. V. Bleininger and Paul Teetor.

THE vitrification of porcelain in the pottery kiln is made possible by lowered viscosity or softening and surface tension which contracts the mass, thus eliminating the pore space. Since no numerical values are available with reference to the degree of softening of porcelain bodies, a series of mixtures were prepared and their viscosity determined at a number of temperatures, between 1160° and 1310° C. The deformation under tensile strain was used as a measure of viscosity. The previously-fired test pieces of suitable shape were suspended from fire-clay grids, and clay weights corresponding to a load of five pounds per square inch attached. After each successive firing to a higher temperature the elongation due to the tensile load was accurately measured. By inspecting the numerical values with reference to composition, it is found that complete vitrification is not possible with less than 19 per cent. of feldspar. Excess of feldspar is undesirable owing to the lowered viscosity brought about by it. The higher the kaolin content, the less marked does the effect of feldspar become. A sharp line of demarcation appears between the bodies containing less than 45 per cent. clay and those of higher clay content. The

former possess a very much higher temperature coefficient of viscosity decrease and hence are more subject to deformation. A lower clay content than 45 per cent. is hence undesirable and may explain the difficulties experienced with bodies of the Seger porcelain type. The strength of porcelain bodies under tensile stress, at the kiln temperatures considered, has been found to be quite low, approaching five pounds per square inch quite closely with maximum elongation, and is but a small fraction of the tensile strength at ordinary temperatures. As to the permissible numerical elongation value under a load of five pounds per square inch, no exact deductions can be made, but it probably lies between five and six per cent.

This method of studying bodies is capable of producing valuable results, and might, with advantage, be applied to clays and other mixtures.

THE ACCURACY OF THE FORMULAS FOR THE RATIO, REGULATION, AND PHASE ANGLE OF TRANSFORMERS.

Paper by P. G. Agnew and F. B. Silsbee.

A DETAILED investigation of all the approximations involved in the derivation of the following formulas for ratio, regulation, and phase angle shows that they are as accurate as are required by the precision with which the quantities involved may be experimentally determined:

N = ratio of turns, primary to secondary.

E_1, E_2 = primary and secondary terminal voltages.

$R = R_1 + N^2 R_2$ = equivalent total resistance referred to the primary.

$X = X_1 + N^2 X_2$ = equivalent total reactance referred to the primary.

I, I_0 = load current and exciting current referred to the primary.

$\cos \theta$ = power factor of load.

$\cos \gamma$ = power factor of exciting current.

When \pm signs occur the upper sign should be used for lagging and the lower sign for leading current. A positive phase angle means the reversed secondary leads the primary.

$$\text{Ratio} = N \left[1 + \frac{IR \cos \theta \pm IX \sin \theta}{NE_2} + \frac{(IR \sin \theta \mp IX \cos \theta)}{2 NE_2^2} + \frac{I_0 R_1 \cos \gamma + I_0 X_1 \sin \gamma}{NE_2} \right]$$

$$\text{Per cent. regulation} = 100 \left[\frac{IR \cos \theta \pm IX \sin \theta}{NE_2} + \frac{(IR \sin \theta \mp IX \cos \theta)^2}{2 NE_2^2} \right]$$

$$\text{Phase angle} = \frac{1}{E_1} \left[\begin{array}{l} IR \sin \theta - IX \cos \theta + I_0 R_1 \sin \gamma \\ - I_0 X_1 \cos \gamma \end{array} \right]$$

For most practical work the square terms in the formulas for ratio and regulation may well be omitted.

To test the formula, direct measurements were carried out on two types of lighting transformers by means of the potentiometer method, and covering the whole range of power factors from zero power factor current leading to zero power factor current lagging. The results checked with the values computed by means of the formula from short-circuit and open-circuit data, well within the experimental errors.

POLARIMETRY.*

IN the preparation of this circular two principal objects have been sought: *First*, to put before the public in as concise a form as possible a general view of polarimetry, especially as applied to the testing of sugars; and, *second*, to collect together into a single paper such information in regard to instruments and methods of procedure as may be obtained only by an extended study of the literature on the subject. Much of the data is taken from standard works, but many of the points discussed are treated with the aid of information obtained from the researches carried on at the Bureau of Standards. A considerable portion of this information has not before been generally available.

A short historical sketch of the development of polarimeters is given, followed by a discussion of light sources, in which it is proposed to make the mercury-green line, $\lambda = 546.1\mu\mu$, the standard in polarimetric work instead of the sodium line, $\lambda = 589.25\mu\mu$. The ratio of the rotations of the two lines for quartz equals 0.85074. Points in the design of the Bates type saccharimeter and the effect of different white light sources on saccharimetric

* Abstract Circular, No. 44, 1913.

readings are discussed. The influence of temperature, also, is fully considered. Care must be taken in applying temperature corrections, especially in the polarization of raw sugars. For temperature control at the Bureau of Standards special small thermostats and a thermostated room are used. The latter may be adjusted for any temperature between 15° C. and 40° C., with a maximum variation of 0.3° C. A new polariscope tube is described which is made entirely of metal and rests on shoulders, thus eliminating all danger of unduly tightening the caps when the tube is rotated in the trough of the instrument.

Especial attention is paid to the analysis of raw sugars, and a number of methods are given. The question of clarification is taken up quite fully, and the advantages and disadvantages of the various means pointed out.

A method for the preparation of pure sucrose has been worked out and is described, as are also the methods used for determining the purity of the final product.

The Bureau is prepared to distribute samples of pure sucrose and of pure dextrose. It is also prepared to make tests on any instrument or substance used in polarimetry or saccharimetry which is included in the schedule of test fees listed. Polarimetric work not included in the schedule will be undertaken by special arrangement.

The paper is quite fully illustrated, containing several photographs and a number of diagrams showing the apparatus in detail.

In the appendix are given the U. S. Treasury Department Sugar Regulations and twenty-four tables, collected from various sources, which are of use in the average laboratory.

Niello or Nielled Silver. ANON. (*Brass World*, ix, 10, 347.)—Niello was known hundreds of years ago, and was apparently lost sight of, but came in use again lately. The method of manufacture is: An article of sterling silver or a silver alloy is deeply engraved in the usual manner. The cuts of the engraved design are then filled with silver, copper, and lead *sulphides*. This mixture of sulphides is black and adheres tenaciously to the silver, and instead of the deep engraving there appear black lines. The sulphide is fused into the silver and is the most permanent black known on account of its thickness. Niello is now rarely found in the trade. The best qualities come from Russia and command a high price. The manufacture of Niello dates back to the eleventh century; and Percy, the celebrated

English metallurgist, states an account of it was written by Theophilus or Rugerus, a monk of that period. The mixture used in Russia and Persia for enamelling silver jewelry is stated to be:

	Ounces. Drachms.	
Silver	0	4
Copper	2	4
Lead	3	4
Sulphur	12	0
Ammonium chloride	2	4

Make a paste of the sulphur with water and put it in a crucible. Melt the metals and pour them into the crucible which contains the paste. Cover this, so that the sulphur may not inflame, and then calcine till all excess sulphur is volatilized. Finely pulverize the mass; and make a paste with a solution of ammonium chloride, and rub this paste into the parts to be enamelled. Clean the article and heat it in a furnace until the paste melts and adheres to the metal. Moisten the article with a solution of ammonium chloride and heat in a muffle to redness. The article, when cold, can be rubbed and polished without detaching or altering the enamel, which retains its fine black color.

The proportions of the metals used at various times were:

Authority	Silver. Per cent.	Copper. Per cent.	Lead. Per cent.
Pliny	75.00	25.00	—
Theophilus	66.67	22.22	11.11
Biringuccio	16.67	33.33	50.00
Benvenuto Cellini	16.67	33.33	50.00
Blaise de Vigenère	16.67	33.33	50.00
Perez de Vargas	16.67	33.33	50.00
Georgi (in Russia)	7.69	38.46	53.85
Répertoire of Patent Inventions, 1827 .	5.88	35.30	58.82

The sulphur and ammonium chloride are used as previously described. It is noticeable that the oldest Niello mixture contains the most silver and no lead, while lead is the principal ingredient in the latest. The foregoing method of making nielled silver is costly, since each article must be engraved. It might be cheapened by engraving in relief a steel plate and compressing it against a silver plate between two hard bodies. A great many copies may be obtained from the same matrix.

Gas Engines versus Natural Gas as Fuel. ANON. (*Amer. Mach.*, xxxix, 5, 176.)—When natural gas is used as a fuel under a steam boiler, from 40 to 60 cubic feet per horsepower-hour are required, while the same power can be developed in a gas engine by the consumption of from 9 to 15 cubic feet; so the use of gas under steam boilers is not to be encouraged, if indeed it should be permitted. (From the *Compressed Air Magazine*.)

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, December 17, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 17, 1913.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 12.

The following proposed amendment to the By-laws was presented for first reading:

Article III, Section 10 of the By-laws to be amended as follows:

After "Philadelphia" in the second line add: "except that members of the Army and the Navy shall be considered as non-resident members, irrespective of residence," so that the section, as amended, shall read:

"Non-resident members shall be those who reside permanently at a distance not less than twenty-five miles from Philadelphia, *except that members of the Army and the Navy shall be considered as non-resident members, irrespective of residence.* Transfers of membership from the resident to non-resident class may be granted by the Board of Managers at its discretion in cases of temporary absence of a member from the city for a period of not less than one year."

The following nominations were made for officers and managers to be voted for at the annual election to be held January 21, 1914:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Coleman Sellers, Jr.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), John Birkinbine, Walton Forstall, E. Goldsmith, Harry F. Keller, Louis E. Levy, Richard Waln Meirs, Alexander P. Robinson, and George D. Rosengarten.

For Manager (to serve two years), Marshall S. Morgan.

Mr. J. A. P. Crisfield, Chairman of the Committee on Science and the Arts, then introduced Mr. C. Francis Jenkins, of Washington, D. C., who had been recommended by the Institute to the City of Philadelphia for the award of the John Scott Legacy Medal and Premium for his motion-picture apparatus. The Chairman presented the medal to Mr. Jenkins.

Dr. David T. Day, in charge of Petroleum, Division of Mineral Resources, United States Geological Survey, Washington, D. C., was then introduced and presented the paper of the evening on "Petroleum and Its Derivatives."

The speaker described the present state of the petroleum industry, and gave interesting facts and statistics relating to the wells in California, Texas, Pennsylvania, and other parts of the United States. The subject was illustrated by lantern slides, and numerous specimens of oils from various localities were exhibited. After the address an interesting demon-

stration of moving pictures, showing the operations of boring for oil, the shooting of the well, and the gushers in action, was given.

On motion of Mr. Levy, duly seconded, the thanks of the meeting were extended to Dr. Day.

Adjourned.

R. B. OWENS,
Secretary.

**RESOLUTION ADOPTED BY THE BOARD OF MANAGERS ON
THE COMPLETION OF MR. ALFRED RIGLING'S THIRTIETH
YEAR AS LIBRARIAN OF THE INSTITUTE.**

The Board of Managers of The Franklin Institute, taking note of the completion, on February 13, 1913, of thirty years' continuous service by Alfred Rigling in the library of the Institute, unanimously resolves that there be recorded in the minutes of this Board the following memorial of that anniversary:

The Board of Managers takes this occasion to express its unqualified approbation of the zealous and efficient service rendered to the Institute by its Librarian, Alfred Rigling, and those of its present members whose collaboration in the activities of the Institute extends back to the earlier years of Alfred Rigling's time take this occasion to add in their own behalf, and as voicing the sentiments of colleagues now passed away, a note of high appreciation of the faithful devotion to duty exemplified by Alfred Rigling in his work as Librarian of the Institute throughout all this course of years.

The Board, furthermore, unanimously resolves that this memorial be published in the JOURNAL of the Institute and that an engrossed copy thereof be presented to the Librarian.

Adopted, September 10, 1913.

**ISAAC B. THORN SCHOLARSHIPS IN INSTITUTE'S SCHOOL
OF MECHANIC ARTS.**

Due to the generosity of Miss Mary Thorn, of Philadelphia, the Institute is able to announce the establishment of the above scholarships in memory of her father, an early member of the Institute and for many years a participant in the Institute's activities.

The sum of one thousand dollars has been deposited in trust, the interest of which is to be used for free scholarships in the Departments of Mathematics, Mechanics, and Naval Architecture.

Miss Thorn has also deposited with the Institute a further sum of three hundred dollars for the establishment of a Permanent Resident Membership.

The Board of Managers by resolution acknowledged these gifts on November 12th and extended the thanks of the Institute to Miss Thorn.

COMMITTEE ON SCIENCE AND THE ARTS

PRESENTATION OF THE JOHN SCOTT LEGACY MEDAL AND PREMIUM TO HALCOLM ELLIS.

The John Scott Legacy Medal and Premium was presented to Mr. Halcolm Ellis, Mechanical Director of the Ellis Adding Typewriter Company of Newark, N. J., at the stated meeting of the Institute held Wednesday, November 19th, for his adding typewriter.¹

Dr. George A. Hoadley, in presenting the recipient of this recognition to the President, said:

"The Franklin Institute has been fortunate in having friends who believe in expressing their friendship in a practical way. It is for this reason that the Directors of the Board of City Trusts of the City of Philadelphia have delegated to The Franklin Institute the honor of presenting to those men and women who have made useful inventions the John Scott Legacy Medal and Premium.

"Some years ago the typewriter made its appearance and won its place in our business life. A few years after that the adding machine and the calculator found their places in our business requirements. Both of these devices have now become invaluable.

"Since that time inventors have been trying to devise a machine that would do the work of both these machines at the same time, so that a person using the typewriter might immediately take up the calculating work without the necessity of leaving the machine.

"Such a machine has been built. The knowledge of this invention having come to The Franklin Institute, the matter was turned over to the Committee on Science and the Arts for investigation. The committee recommended that an investigation be made on the merits of this invention. It was found to be a machine which, although made of many parts, had in it simplicity of design and operation; a machine that had in it a feature that is noticeable in all American-made machinery—interchangeability of parts; a machine of practical value.

"Following the favorable report of the Committee on Science and the Arts, The Franklin Institute recommended to the Board of City Trusts the award of the John Scott Legacy Medal and Premium to the inventor of this machine.

"It therefore gives me great pleasure to present to you Mr. Halcolm Ellis, inventor of the combined adding and typewriting machine."

PRESENTATION OF THE JOHN SCOTT LEGACY MEDAL AND PREMIUM TO C. FRANCIS JENKINS.

On recommendation of the Institute, Mr. C. Francis Jenkins, of Washington, D. C., was awarded the John Scott Legacy Medal and Premium for his motion picture apparatus.² The presentation was made at the stated

¹ J. F. I., December, 1913, p. 723.

² Page 95.

meeting of the Institute held Wednesday evening, December 17, 1913, and in presenting the recipient to the President of the Institute, Mr. J. A. P. Crisfield, Chairman of the Committee on Science and the Arts, said:

"Before presenting to you the subject which the managers of the Institute have provided for our instruction and amusement this evening, I desire to announce to you that we will first perform one of our time-honored and most respected ceremonies, namely, the recognition by the Institute of the meritorious work of an inventor.

"The Certificate of Merit of The Franklin Institute has ever been a highly-prized possession, but when accompanied, as it will be to-night, by a medal of enduring metal, paid for through the self-denial of one who has long since joined his fathers, the recipient of this recognition by the Institute is doubly honored.

"The man who will receive to-night these awards for a useful invention, cunningly conceived and skilfully executed, has probably done more to perfect the moving-picture machine and to widen its field of usefulness than any other.

"This simple statement should be sufficient to excite in us a feeling of gratitude to him who has so largely contributed to our amusement and education by materially assisting in bringing the moving-picture machine to its present high state of development. Mr. President, I take pleasure in introducing to you Mr. C. Francis Jenkins, of Washington, D. C."

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
December 3, 1913.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 3, 1913.

MR. J. A. P. CRISFIELD *in the Chair.*

The following report was presented for final action:

No. 2537.—Cooper Hewitt Mercury Arc Rectifier. Elliott Cresson Medal. Adopted.

The following reports were presented for first reading:

No. 2539.—Duplex Copper Steel Wire. Advisory. Adopted.

No. 2540.—Upton Lewis Fatigue Testing Machine. Deferred.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on Thursday, November 13, at 8 o'clock P.M., with Dr. George A. Hoadley in the chair. One hundred and three members and visitors were present.

The minutes of the previous meeting were read and approved.

P. W. Bridgman, A.M., of the Jefferson Physical Laboratory of Harvard University, delivered an address on "High Pressures and Five Kinds of Ice."

The cylinder, piston, packing, and pressure gauges used in studying the action of exceedingly high pressures upon water were described. The region of each of the five kinds of ice, one of which exists as a solid at 160° F., was shown by means of curves and lantern slides. New phases or allotropic modifications of phosphorus, carbon tetrachloride, and other compounds, discovered by a study of their behavior at high pressures, were also mentioned.

The paper was discussed at length, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Wednesday evening, November 26th, at 8 o'clock.

Mr. J. A. P. Crisfield, member of the Institute, and Mr. Clarence P. Wynne, President of the Aëro Club of Pennsylvania, presided jointly.

Mr. Crisfield introduced Dr. A. F. Zahm, of Washington, D. C., who, in a paper entitled "Recent Developments in Aëromechanics," gave an account of the most recent researches in aëromechanics in the principal European laboratories.

The paper was illustrated by about fifty lantern slides.

After some discussion, the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, December 4th, at 8 o'clock.

Professor A. E. Outerbridge, Jr., and Mr. A. R. Cheney presided jointly.

Professor Outerbridge introduced Mr. D. A. Lyon, A.M., Metallurgist, United States Bureau of Mines, Washington, D. C., who presented a paper entitled "Some Present-day Metallurgical Problems."

The speaker dealt with the extensive application of the electric furnace, the utilization of slag, fuel economy in smelting, and the question of iron and steel corrosion. He outlined the possibilities for invention in the smelting of sandy, sulphuretted, and complex ores. He concluded with remarks on direct-process methods of smelting, without intermediate steps.

After some discussion, the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, December 11th, at 8 o'clock. Dr. Walton Clark presided.

The minutes of the previous meeting were approved as published.

The Chairman introduced Mr. J. Waldo Smith, C.E., Chief Engineer, Board of Water Supply, New York City, who presented a paper on "The Catskill Water Supply for New York City."

Mr. Smith described the construction of the ninety-two-mile aqueduct for bringing water from the Catskill Mountains to New York City. By means of lantern slides, he illustrated the making of the tunnel, cut and cover, and open portions of the aqueduct, showing the methods employed in reinforcing the structure, particularly the deeper portions, as, for instance, where it passes under the Hudson River.

After some discussion the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting of the Board of Managers, December 10, 1913.)

RESIDENT.

MR. LEWIS J. STERN, 1805 Spring Garden Street, Philadelphia, Pa.

NON-RESIDENT.

MR. ONWARD BATES, 332 South Michigan Avenue, Chicago, Ill.

MR. JOHN W. CLOUD, 82 York Road, King's Cross, London, N., England.

MR. R. T. CRANE, III, Crane Company, 836 South Michigan Avenue, Chicago, Ill.

MR. E. R. FELLOWS, Fellows Gear Shaper Company, Springfield, Vt.

MR. A. L. JOHNSON, Corrugated Bar Company, Mutual Life Building, Buffalo, N. Y.

MR. GUSTAV LINDENTHAL, 68 William Street, New York, N. Y.

MR. HUNTER McDONALD, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

MR. AUGUSTUS SMITH, foot West Fifth Street, Bayonne, N. J.

MR. H. R. STANFORD, U.S.N., Chief of Bureau of Yards and Docks, Navy Department, Washington, D. C.

ASSOCIATE.

MR. ALLEN DOUGLAS IRVINE, 523 Commercial Trust Building, Philadelphia, Pa.

MR. ATHERTON H. MEARS, Spencer Street, Logan Station, Philadelphia, Pa.

Changes of Address.

- MR. ALFRED E. BURK, 925 North Third Street, Philadelphia, Pa.
MR. G. W. CHANCE, 3421 North Eighteenth Street, Philadelphia, Pa.
MR. JOHN W. HORNSEY, Searles, Cal.
MR. NELSON B. MAYER, Hotel Marie Antoinette, Broadway and Sixty-seventh Street, New York City.
MR. ERNEST. H. RIGG, 51 Delaware Street, Woodbury, N. J.
MR. J. WALDO SMITH, Municipal Building, New York City.
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LIBRARY NOTES.**Purchases.**

- BRUNSWIG, H.—Explosives. 1912.
COLVIN, F. H., and L. L. HAAS.—Jigs and Fixtures. 1913.
DYKE, A. L.—Dyke's Automobile Encyclopedia. Ed. 3. 1913.
GIBSON, C. R.—Wireless Telegraphy and Telephony. 1914.
HAYES, H. V.—Public Utilities. 1913.
JONES, H. C.—New Era in Chemistry. 1913.
KARAPETOFF, V.—The Electric Circuit. 1912. Ed. 2.
LINDGREN, W.—Mineral Deposits. 1913.
LOW, A. H.—Technical Methods of Ore Analysis. Ed. 6. 1913.
McCULLOCH, G., and T. C. FUTERS.—Winding Engines and Winding Appliances. 1912.
PRIMROSE, J. S. C.—Practical Metallography. No date.
RAMBOUSEK, J.—Industrial Poisoning. 1913.
RECTOR, F. L.—Underground Waters. 1913.
REED, S. J.—Turbines Applied to Marine Propulsion. 1913.
REGENBOGEN, C.—Building of Diesel Engines at Krupp's. 1913.
SEGERBLOM, W.—Tables of Properties. 1909.
SMITH AND WARREN.—New Steam Tables. 1912.
SMITH, E. F.—Elements of Electrochemistry. 1913.
SMITH, E. F.—Theories of Chemistry. 1913.
SMITH, E. F., and H. F. KELLER.—Experiments for Students in General Chemistry. 1913.
SPRINGER, J. F.—Oxy-acetylene Torch Practice. No date.
STILL, A.—Overhead Electric Power Transmission. 1913.
SYDNEY, S.—Mechanical Refrigeration. 1913.
TAYLOR, W. T.—Transformer Practice. Ed. 2. 1913.
TOLMAN, W. H., and L. B. KENDALL.—Safety Methods. 1913.
WAKEMAN, W. H.—Pumps and Pumping Machinery. 1912.
WHITE, A. H.—Techinal Gas and Fuel Analysis. 1913.
WOODWARD, C. M.—Rational and Applied Mechanics. 1912.

Gifts.

- American Society of Civil Engineers, Transactions, vol. 76. 1913. New York, 1913. (From the Society.)

- Australia Bureau of Census and Statistics; Official Year Book, No. 6. 1913. Shipping and Oversea Migration for 1912. Melbourne, 1913. (From the Bureau.)
- Baltimore & Ohio Railroad Company, 87th Annual Report, 1913. Baltimore, 1913. (From the Company.)
- Barlow's Tables of Squares, Cubes, etc. London, 1897. (From Mrs. H. C. Heckendorn.)
- Canada Department of Customs, Report March 31, 1913. Ottawa, 1913. (From the Department.)
- Canada Department of Mines: Memoir No. 37, Portions of Atlin District, British Columbia, by D. D. Cairns. The Production of Copper, Gold, Lead, etc., in Canada during 1912 and Summary Report of the Mines Branch for 1912. Ottawa, 1913. (From the Department.)
- Canadian Society of Civil Engineers, Transactions, vol. 27, pt. 1. 1913. Montreal, 1913. (From the Society.)
- Colgate University, Autumn Bulletin, The College. Hamilton, N. Y., 1913. (From the University.)
- Council of Arts and Manufactures of the Province of Quebec, Rules and Regulations of the Free Drawing and Industrial Classes, 1913-1914. Montreal, 1913. (From the Council.)
- Fleming, J. A.—Alternate Current Transformer. London, 1894. (From Mrs. H. C. Heckendorn.)
- Great Britain Board of Trade, 16th Abstract of Labour Statistics. London, 1913. (From the Board.)
- Great Northern Railway Company, 22d Annual Report, June 30, 1911. St. Paul, 1913. (From the Company.)
- Hopkins, G. I.—Manual of Plane Geometry. Boston, 1891. (From Mrs. H. C. Heckendorn.)
- Houston, E. J., and A. E. Kennelly.—Recent Types of Dynamo Electric Machinery. New York, 1898. (From Mrs. H. C. Heckendorn.)
- Hutchinson, W. B.—Patents and How to Make Money out of Them. New York, 1899. (From Mrs. H. C. Heckendorn.)
- India Inspector General of Forests, Annual Return of Statistics Relating to Forest Administration in British India, 1911-1912. Simla, 1913. (From the Inspector General.)
- Institution of Naval Architects, Transactions, vol. 55, 1913, pt. 1. London, 1913. (From the Institution.)
- Isthmian Canal Commission, Canal Record, vol. 6, 1912-1913. Ancon, Canal Zone, 1913. (From the Commission.)
- Kapp, G.—Electric Transmission of Energy. London, 1891. (From Mrs. H. C. Heckendorn.)
- Manchester Steam Users' Association: Boiler Explosions Act, 1882. Board of Trade Reports 2073-2178. London, 1913. (From the Association.)
- Massachusetts Institute of Technology, Catalogue December, 1913. Boston, 1913. (From the Institute.)
- Mellon Institute of Industrial Research and School of Specific Industries, Bulletin No. 3, Psychological Aspects of the Problem of Atmospheric Smoke Pollution, by J. E. W. Wallin. Pittsburgh, 1913. (From the Institute.)

- Minneapolis Water Works, Annual Reports of the Registrar and Supervisor, 1912. Minneapolis, Minn., 1913. (From the Works.)
- New Jersey Geological Survey: Bulletin 10, The Mechanical and Chemical Composition of the Soils of the Sussex Area, New Jersey. Bulletin 11, The Mineral Industry of New Jersey for 1912. Trenton, 1913. (From the Survey.)
- New York State Library, 94th Annual Report, 1911. Albany, 1913. (From the Library.)
- Oklahoma Geological Survey, Bulletin No. 11, Gypsum and Salt of Oklahoma, by L. C. Snider. Norman, 1913. (From the Survey.)
- Ontario Bureau of Mines, 22d Annual Report, 1913, pt. 1. Toronto, 1913. (From the Bureau.)
- Ontario Department of Agriculture: Annual Report of the Bee-Keepers' Association, 1912, and Annual Reports of the Dairymen's Associations, 1912. Annual Report of the Farmers' Institutes, 1913, pt. 2. Annual Report of the Women's Institutes, 1913, pt. 1. Toronto, 1913. (From the Department.)
- Peabody Institute, 46th Annual Report, 1913. Baltimore, 1913. (From the Institute.)
- Pennsylvania: Vetoes by the Governor, 1913. Report of the State Librarian, 1912. Laws of Pennsylvania, 1913. Message of the Governor of Pennsylvania to the General Assembly, January 7, 1913. Annual Report of the Superintendent of Public Printing and Binding, June 30, 1912. Annual Report of the Secretary of Internal Affairs, pt. 4, June 30, 1912. Pennsylvania Report of the Commissioner of Banking, 1912, pt. 1. Harrisburg, 1913. (From the State Librarian.)
- Pere Marquette Railroad, Annual Report, 1913. Detroit, no date. (From the Railroad.)
- Pratt and Whitney Company, Precision Tools. Hartford, Conn., 1904. (From Mrs. H. C. Heckendorn.)
- Raynes, F. W.—Heating Systems. London, 1913. (From Mrs. H. C. Heckendorn.)
- Royal Society of London, The Celebration of the Two Hundred and Fiftieth Anniversary, July, 1912. London, 1913. (From the Society.)
- Slingo, W., and A. Brooker.—Electrical Engineering. New York, 1898. (From Mrs. H. C. Heckendorn.)
- Smith College, Catalogue 1913-1914. Northampton, Mass., 1913. (From the College.)
- Standage, H. C., comp.—Cements, Pastes, Glues, and Gums. London, 1897. (From Mrs. H. C. Heckendorn.)
- Vermont Historical Society, Proceedings 1911-1912. Montpelier, 1913. (From the Society.)
- Western Reserve University, Reports of the President and Other Officers, 1912-1913. Cleveland, 1913. (From the University.)
- Wisconsin Agricultural Experiment Station, 29th Annual Report, 1912. Madison, 1912. (From the Station.)
- Yonge, C. D., comp.—English-Greek Lexicon. New York, 1886. (From Mrs. H. C. Heckendorn.)

PUBLICATIONS RECEIVED.

Le Chatelier, Henry.—Eau oxigénée et ozone. Memoires de Thénard, Schoenbein, de Marignac, Soret, Troost, Hautefeuille, Chappuis. Les Classiques de la Science, vol. iii. 111 pages, plate, 12mo. Paris, Armand Colin, 1913. Price, 1.20 francs.

LeMoine, Jules.—Mesure de la Vitesse de la Lumière. Étude optique des Surfaces. Mémoires de Léon Foncault. Les Classiques de la Science, vol. ii. 123 pages, plates, 12mo. Paris, Armand Colin, 1913. Price, 1.30 francs.

Rein, H.—La Technique de la Radiotélégraphie. Traduit de l'Allemand d'après la deuxième édition par G. Viard. 262 pages, illustrations, plates, 8vo. Paris, Gauthier-Villars, 1913. Price, 9 francs.

Canada, Department of Mines, Summary Report of the Mines Branch for the Calendar Year Ending December 31, 1912. 174 pages, illustrations, plates, maps, 8vo. Ottawa, King's Printer, 1913. Price, 15 cents.

Ontario Bureau of Mines, Twenty-second Annual Report 1913, being vol. xxii, pt. 1. 284 pages, illustrations, maps, 8vo. Toronto, King's Printer, 1913.

Pennsylvania Topographic and Geological Survey, Report of the Work Accomplished during the Fiscal Years Ending June 30, 1911, and June 30, 1912. 182 pages, illustrations, plates, maps, 8vo. Harrisburg, State Printers, 1912.

United States Secretary of Commerce, Annual Report, 1913. 151 pages, 8vo. Washington, Government Printing Office, 1913.

Canada, Department of Mines, Mines Branch: The Production of Iron and Steel in Canada during the Calendar Year 1912, by John McLeisch, B.A., Chief of the Division of Mineral Resources and Statistics. 39 pages, 8vo. The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada during the Calendar Year 1912, by Cosmo T. Cartwright, B.Sc., Assistant Mining Engineer, Division of Mineral Resources and Statistics. 86 pages, 8vo. Ottawa, Government Printing Bureau, 1913.

United States Bureau of Mines: Bulletin 69, Coal Mine Accidents in the United States and Foreign Countries, compiled by Frederick W. Horton. 102 pages, 8vo. Bulletin 70, A Preliminary Report on Uranium, Radium, and Vanadium, by Richard B. Moore and Karl L. Kithil. 101 pages, illustrations, plates, map, 8vo. Miners' Circular 13, Safety in Tunnelling, by David W. Brunton and John A. Davis. 19 pages, 8vo. Monthly Statement of Coalmine Fatalities in the United States, September and October, 1913, with revised figures for preceding months, compiled by Albert H. Fay. Technical Paper 30, Mine Accident Prevention at Lake Superior Iron Mines, by Dwight E. Woodbridge. 38 pages, illustrations, 8vo. Washington, Government Printing Office, 1913.

Mellon Institute of Industrial Research and School of Specific Industries, Smoke Investigation Bulletin No. 3, Psychological Aspects of the Problem of Atmospheric Smoke Pollution, by J. E. Wallace Wallin, Ph.D., Director of Psychological Clinic, University of Pittsburgh. 46 pages, 8vo. Pittsburgh, University of Pittsburgh, 1913.

United States Department of Agriculture: Bulletin No. 9, An Economic Study of Acacias, by Charles Howard Shinn, Forest Examiner. 38 pages, illustrations, plates, 8vo. Office of Public Roads: Report of the Director for the Fiscal Year ended June 30, 1913. 13 pages, 8vo. Washington, Government Printing Office, 1913.

Hodges, Leroy.—Training for Citizenship. An article on the Winston-Salem plan of training for citizenship. 5 pages, 8vo. Washington, Government Printing Office, 1913.

New Method of Preparing Argon. J. STARK. (*Phys. Zeitschr.*, xiv, 497.)—When oxygen issues from a cylinder into a vacuum tube containing mercury vapor a reddish-yellow deposit of mercury oxide appears on the glass. The canal-ray spectrum shows mercury and strong argon lines, but little oxygen and no nitrogen. The commercial oxygen obtained by the evaporation of liquid air contains about 6 per cent. nitrogen and 4 per cent. argon. The oxygen and nitrogen combine with the mercury in the glow discharge and leave the argon free. A simple arrangement is described for utilizing this process in preparing spectroscopically pure argon. Not only are nitrogen and oxygen rendered active by the glow discharge, but also hydrogen and iodine vapor.

CURRENT TOPICS

International Electrical Congress, San Francisco, 1915.—The International *Electrical* Congress is to be held at San Francisco, September 13th to 18th, 1915, during the Panama-Pacific International Exposition, under the auspices of the American Institute of Electrical Engineers, by authority of the International Electrotechnical Commission. Dr. C. P. Steinmetz has accepted the honorary presidency of the Congress. The deliberations of the Congress will be divided among twelve sections, which will deal exclusively with electricity and electrical practice. There will probably be about 250 papers. The first membership invitations will be issued in February or March, 1914.

Attention is drawn to the distinction between this Electrical Congress and the International *Engineering* Congress which will be held at San Francisco during the week immediately following the Electrical Congress. The Engineering Congress is supported by the Societies of Civil, Mechanical, and Marine Engineers and by the Institutes of Mining and Electrical Engineers, as well as by prominent Pacific Coast engineers who are actively engaged in organizing it. This Congress will deal with engineering in a general sense, electrical engineering subjects being limited to one of the eleven sections which will include about twelve papers, treating more particularly applications of electricity in engineering work.

The meeting of the International Electrotechnical Commission will be held during the week preceding that of the Electrical Congress.

New Use for Aluminum. ROBERT GRIMSHAW. (*Metal Industry*, x, No. 9, 380.)—Leon Guillet, in a paper read before the French Society of Civil Engineers, called attention to two new forms of aluminum which have recently been used in large quantity, viz., the production of aluminum powder and aluminum foil. The powder is produced from the foil. Aluminum foil is gradually displacing tin foil for wrapping articles of food such as cheese, and especially chocolate. Long and expensive experiments were conducted before a means was found to roll the metal sufficiently thin. According to *La Nature*, the rolling is effected in the factory at La Praz in six stages, the last of which yields a foil which is only 0.04 mm. (0.0016 inch) thick. In order to get a still thinner foil several sheets are laid together and either rolled as a whole or beaten, as is done with gold leaf. To make aluminum powder, foil only 0.01 mm. thick (0.0004 inch) is cut into squares of 2 mm. on the side and rubbed to powder. This powder is used to make aluminum paint. It feels like salve, or rather like graphite, and is very difficult to remove from the hands.

Phosphate Industry of Egypt. ANON. (*Board of Trade J.*, Sept. 4, 1913.)—The exploitation of the phosphate deposits in Egypt was commenced in 1908, and the growth of the output of phosphates since then is shown by the following figures: In 1908, 700 tons; in 1909, 1,000 tons; in 1910, 2,397 tons; in 1911, 6,425 tons; in 1912, 69,958 tons. As there is no factory in Egypt for the manufacture of superphosphates, and as the local demand for phosphates as fertilizer is at present negligible, practically all the phosphate mined is now exported. There are many low-grade deposits, however, which may in time become of commercial value if a demand should arise for raw phosphate as a fertilizer.

The Combustion of Gaseous Mixtures and Retardation on Ignition. TAFFANEL and LE FLOCH. (*Comptes Rendus*, clvi, 1544.)—The course followed by the combustion of mixtures of methane and air is studied by introducing small quantities of the mixtures into an evacuated silica flask which has 300 c.c. content and is heated electrically. By means of a special cock, which opens and closes automatically, this introduction is effected in less than 0.03 second, and 0.05 to 0.12 second after the shutting of the cock the mean temperature of the gas differs from that of the wall of the flask by only about 10° . A registering manometer records photographically the variation of pressure in the flask as a function of the time. The ignition of mixtures of methane and air, which is rendered evident by the flash and also by a sharp rise in pressure, occurs only after the lapse of a certain time, varying with the temperature of the flask and with the composition of the gaseous mixture. This retardation is observed also with moist mixtures of the gases, so that the usual explanation—that explosive combustion requires the presence of a certain quantity of water—falls to the ground. It seems rather that the velocity of reaction of these gaseous mixtures increases with the temperature less rapidly than with mixtures which exhibit no such retardation.

Production of Diamonds in Electric Furnaces. F. P. MANN. (*Met. and Chem. Engin.*, xi, 361.)—Gives an account of the experiments made by E. de Boismenu at Paris in 1908 and described by him in a pamphlet entitled "Fabrication Synthétique du Diamant." Fused calcium carbide is electrolyzed for hours in an electric furnace fitted with two horizontal carbon electrodes 24 cm. apart. "Enriched" carbide is afterward found near the anode; farther away the carbide is undecomposed, but near the kathode a black mass of carbon is observed, from which a few flakes of graphite and some irregular, colorless crystals or globules can be isolated, which were pure carbon, according to Lacroix and Maquenne. The length of the crystals increased with the duration of the electrolysis, from 1.5 mm. in six hours to 2.7 mm. in twelve hours. The process is covered by French Patent No. 4566 of August, 1907.

New Multiple Relations of the Atomic Weights of Elementary Substances; Classification and Transformations of Neon and Helium. H. WILDE. (*Manchester Lit. and Phil. Soc. Mem.*, lvii, Part 3, No. 12.)—In several of the author's papers on the "Origin of Elementary Substances" special attention was directed to the seventh series of his classification, on account of the magnitude and importance of its primary members in the economy of nature, namely: nitrogen, silicon, gold, and iron. Silicon in combination with oxygen constitutes more than half the weight of the earth's crust. The arbitrary policy of several writers in doubling the atomic weights of four of the gaseous members of this series (neon, argon, krypton and xenon) induced the author to review the multiple relations of the seventh series with this important result: That six triads are formed out of the eighth principal members of the series, in which the sum of the atomic weights of the extreme members is double the atomic weight of the means, and are all multiples of seven. Triads of atomic weights have been fully recognized by Dumas, Faraday, and others, as indubitable evidence of community of origin, of transmutation, and as important factors in the classification of elementary substances. Radium is one of the synthetic transformations of helium, and is the next higher member of the series to barium, as was confirmed by Mme. Curie. Helium is also shown as the analytic transformation ultimate of radium and other members of the second series of elements. The positions of helium and neon, as the transformation ultimates of the second and seventh series respectively, are further interesting in connection with the recent announcements that these elements have been found in glass vessels and tubes in which they had no previous existence. Assuming the truth of these observations, the phenomena are not only explicable by the author's classifications, but also account for the discordant results obtained by the experimenters engaged in the research. One of the investigators could only find neon, while others, working independently, found only helium, and others a mixture of both gases. These results were sufficiently interesting to induce the author to ascertain the composition of various glasses used in the arts. The principal and most important constituent of the glasses examined by the author is silicon,—the transformation ultimate of which is neon. The next important constituents are barium, calcium, and lead,—all members of the second series of elements, the transformation ultimate of which is helium. The alkali metals, sodium and potassium, are constituents of nearly all glasses, and their transformation ultimates (with others of the first series) will be hydrogen and neon, but without helium. All the silicates of the first and second, and some of other series, are easily vitrified in small quantities in laboratory crucibles. Their spectra can then be examined during electrification in tubes (under suitable conditions of temperature and pressure) for the discovery of new elements and the identification of those already known.

Magnetic Normal Triplet and Preston's Law. R. FORTRAT. (*Comptes Rendus*, clvi, 1607.)—Paschen and Black have shown that the oxygen triplet λ 3947 gives, in a sufficiently intense field, a magnetic triplet very closely approximately the normal. This paper describes a similar research with the sodium doublet λ 2852.828, 2853.031. In a weak field the decomposition follows Preston's rule. In a field of 34,400 gauss two anomalies present themselves. These are described with the aid of a diagram. With a field of 44,500 gauss most of the regular components could be distinguished, but with very abnormal intensities and polarizations, and with displacements considerably greater than the errors of observation. In a field of 47,600 gauss, in place of the ten components given by Preston's rule, only a triplet is found; the side component on the short wave-length side is sharp, the central component and the other side component being broader. Measurements of the distances between the sharp line, the most intense part of the central line, and the middle of the other side line, show that the triplet is nearly normal. It appears probable that a field of 50,000 gauss would give an exact normal triplet with sharp components. Fortrat has previously shown that in certain bands the doublets and triplets are reduced by a magnetic field to a single line. This fact throws some light on the present results, since it now appears that both a doublet and a triplet behave, in sufficiently strong fields, as if formed of a single line.

Under Cooled Steam. ANON. (*Engineering*, xcv, 673.)—This paper considers the condensation of steam according to the views of Aitken, C. T. R. Wilson, and J. J. Thomson,—i.e., as a result of the presence of nuclear dust, electrons, or drops of liquid. These considerations are applied to ordinary boiler steam conditions and a recent article of Stodola (in *Schweiz. Bauzeitung*) is criticised. The loss in turbine nozzles due to undercooling is, according to Stodola, not more than 1 per cent. *Engineering* disagrees, and shows that the loss may be very much more. The current view that moist steam is less efficient on account of higher friction is opposed, and undercooling with subsequent reversion to thermal equilibrium is put forward as the main cause of loss.

Recovering Oil and Waste. ANON. (*Electr. Rwy. Journ.*, xlii, 62.)—The Denver City Tramway Company cleans the oil and waste used in the car journals in a tank 5 feet 6 inches long, 3 feet 6 inches wide, and 17 inches high, in which is a horizontal screen on which the picked waste rests. Clean, hot oil is poured over the waste, and after this oil has dripped away the waste can be used again. The oil used for washing is filtered and used again. About 150 pounds of journal and armature waste are worked through the tank every week. No new waste has been purchased since December, 1912, when the plant was first used. All car motors are oiled every ten days.

Simplification of Spectral Lines by Magnetic Field. R. FORTRAT. (*Comptes Rendus*, clvi, 1459.)—Various experimenters have shown that in very strong magnetic fields certain groups of spectral lines are simplified. In this paper Fortrat describes the action of a magnetic field on certain band spectra, and shows that a large number of naturally multiple lines are simplified by the action of the field, in this case of 40,000 gauss. A diagram is given of the effect on the green band of carbon. The action of the field reduces all the doublets to simple lines, and the triplets are also reduced to simple lines for all frequencies above 1949. The blue band of the Swan spectrum gave similar results, as did also the spectrum of the negative pole of nitrogen. The phenomenon thus appears to be a general property of band spectra.

Electrical Propulsion of Submarines. G. MARIN. (*Electricien*, xlvi, 101.)—The electrical interest of submarine navigation is referred to, and it is affirmed that, but for the use of electricity, this branch of naval practice would have offered almost insuperable difficulties. It is imperative that the propelling machinery should be as efficient and compact as possible, while being absolutely reliable. Silent and flexible operation is required, and it is desirable that no exhaust gases should be expelled which might disclose the position of the vessel to an enemy. The constancy of weight of the vessel where electricity is employed is a further advantage. The general problems encountered in the electrical propulsion of submarines resemble those of storage battery traction on land. Two independent battery, motor, and control equipments are generally provided, one on each side of the vessel; the capacity of each motor in modern submarines being about 800 horsepower. In port the batteries may be charged from a central station supply, but at other times the motors are driven as dynamos by the oil or steam engines used for surface propulsion. In respect of flexibility and reliability steam engines are preferable to oil engines, but the former require boilers and involve further weight and space difficulties. The *Gustave-Zédé* has two Belleville engines of 1500 horsepower, and the use of steam turbines in submarines is now considered. Electrical energy is generally distributed and employed at 240 volts pressure in modern submarines; higher voltages would be advantageous but for the difficulty of maintaining insulation in the humid atmosphere within a submarine and the undesirability of high-tension apparatus in the limited space available. The Siemens-Schuckertwerke have provided 440-volt supply on board the *Vulcan*. Submarines of nearly 1000 tons displacement have been built, and much larger vessels are under construction. Traction-type batteries are used to store maximum energy in minimum space. The following values are given for weight and cost (per one kilowatt-hour capacity on three-hour discharge) of various types of accumulators: Lead (Planté), 73.5

kg./196 fr.; lead (pasted), 62 kg./200 fr.; lead (high capacity), 56 kg./190 fr.; Edison (iron-nickel), 42 kg./340 fr. The lead accumulator is the only type used, so far, in submarines, but the Edison cell, though costly, offers advantages in respect of lightness, compactness, strength, freedom from sulphation, and avoidance of acid. Practical experience is required to determine whether the Edison cell is advantageous in such large sizes as are required for submarine work. Speed regulation by field control is convenient and efficient; it may be combined with series-parallel control, the latter being applied not to the two main motors, but to the two armature windings of a double commutator motor or to the two halves of each battery. The starboard and port batteries, control gears, and motors are generally kept quite independent. The main switch-gear is of the contactor type, controlled by master switches; graduated electro-dynamic braking is provided for the motors. It is usual to specify 90 per cent. full-load efficiency for the motors of a submarine carrying two 590-kilowatt machines; the electrical losses in the motors then amount to 118 kilowatts at full load; further heating is caused by the starting rheostats, which may attain 200° C.

Analyses of Coals in the United States. N. W. LORD. (*United States Bureau of Mines, Bulletin 22.*)—This contains analyses of 5000 samples of coal taken from 1500 coal mines. The purpose of the bureau in compiling and publishing this information is to give reliable data regarding the chemical composition and thermal value of the coals. The samples were collected by experienced men according to a definite and uniform system, and were analyzed under carefully-controlled conditions, so that there might be no question as to the relative merits of the different coals so far as this can be determined by chemical analyses and determinations of the heating values.

New Torque Meter. H. GÖRGES and P. WEIDIG. (*Elektrotechn. Zeitschr.*, xxxiv, 701.)—This mode of measurement is an improvement on the brake principle, as it transmits instead of absorbing the energy. A flexible coupling of the Siemens-Schuckert type, connected by leather rings, is used for transmitting the energy. Suitable mirrors are mounted on the spindles on each side of the coupling. The first mirror receives light from a source, reflects it to a second external mirror, which then reflects it again to the one which is mounted on the other side of the coupling, from which it is transmitted to the eyepiece of a telescope. Supposing that no torque is being transmitted, the eyepiece receives an image of the source of light, but when the torque is transmitted, either the telescope or the source of light must be displaced in order that the image may be received on the eyepiece. The amount of this displacement is a measure of the torque.

Incandescent Gas Light Chimneys in the Flame. ROBERT SCHALLER. (*J. Gasbel.*, lvi, 317.)—The Jena works have produced a new glass called "Suprax" for lamp chimneys. If a piece is heated in a pointed blast flame, till a circular spot is softened, then cooled, and the heated spot scratched with a diamond, only one sample out of many cracked, while all other glasses submitted to the same test cracked badly. Devitrification, formation of a dusty coating of sodium sulphate from the sulphur in the gas, and the formation of copper red spots from particles of brass from the burner, are given as faults of the old glasses, and this new glass is stated to be much more resistant to similar action than any other.

Production of Radio-active Substances from Thorium. F. GLASER. (*Chem. Zeit.*, xxxvii, 1105.)—The precipitation of thorium X from a thorium solution obtained from monazite sand with sulphuric acid is conditioned by the presence of lead which, as lead sulphate, absorbs thorium X, and thorium X may be separated from any thorium solution containing sulphuric acid by the addition of a little lead acetate. Other lead salts do not behave like lead sulphate in this respect, so that by treating the radio-active lead sulphate with sodium carbonate solution, dissolving the washed residue in hydrochloric acid, and precipitating with hydrogen sulphide, the lead may be separated as sulphide, leaving thorium X in solution.

Influence of the Sizing of Paper on the Resistance of the Text of Documents to Removal by Mechanical or Chemical Means. H. FREDERKING. (*Mitt. K. Material-Prüfungsamt*, xxxi, 195.)—The harder the surface sizing and the closer the surface texture of the paper, the more readily are written, typewritten, or stamped characters removed. A striking exception to this rule is the case of parchment papers, from which characters in writing ink can seldom be removed entirely without trace. Such papers, however, hardly fall within the range of practical application for documents. As a guard against falsification, document papers should be relatively soft-sized. Papers sized with resin are to be preferred, from this point of view, to papers sized with gelatin, because certain of the chemical ink-removing agents leave stains on resin-sized papers. The prejudice against typewriting for documents is scarcely justified, since many brands of modern typewriter ribbons give characters as difficult to remove as characters written in ink, sometimes even more resistant. The treatment of documents with a protective varnish is of little value as a safeguard against falsification; such varnishes cause the spreading of typewritten or stamped characters and are only available for documents written in ink. With hard tub-sized papers the varnish remains on the surface and is easily removed by solvents, while with softer-sized papers the protection afforded by the varnish is so slight that it does not compensate for the unsightly appearance produced.

The Humphrey Pump. H. A. HUMPHREY. (*Engineering*, xcv, 708.)—The author suggests various modifications. An experimental plant has shown practically the same efficiency at high as at low lifts, and a continental licensee has devised an arrangement for securing good compression pressure under a low delivery head. The use of air vessels is indicated, and a symmetrical arrangement of two pumps suggested. An adaptation is described by which heavy oils may be used with an externally-heated carburettor. The oscillating mass of dead water may be replaced by a metallic piston. This gives the same inertia with much less bulk, and by this method the rate of reciprocation has been increased to 193 cycles per minute. Curves are given showing the thermal efficiency of the pump cycle contrasted with that of the Otto cycle gas engine at various compression pressures.

The Displacement of the Critical Points of Iron by the Addition of Silicon. G. CHARPY and A. CORNU. (*Comptes Rendus*, clvii, 319.)—The point a_3 occurs at a slightly higher temperature and becomes less marked as the silicon content rises, and disappears at about 1.5 per cent. silicon. The point a_2 occurs at a lower temperature as the silicon increases, but does not change in intensity. In low carbon steels the fall is 10° to 12° C. for 1 per cent. silicon. The point A_1 rises slightly on the temperature scale as the silicon increases. It tends at the same time to become less marked, in consequence of the transformation of the carbon into graphite in presence of the silicon, and disappears when the silicon exceeds about 5 per cent. The extent to which the carbon is transformed into graphite, and hence the intensity of the a_1 transformation, is partly determined by the heat treatment. In steels with more than 3.2 per cent. silicon, a_1 is higher than a_2 on the temperature scale.

Recovery of Lost Handwriting by Photography. A. JENCIC. (*Wiener Mitt.*, 1913, 299.)—Ultraviolet light photography is of limited availability, but as most ancient and modern inks are acid, the following methods are often successful. Nitrated silver chloride paper is kept in contact with the faded text for 12 hours or more, then exposed to full light, when the writing shows in metallic lustre on a dark ground. The image cannot be fixed, but is stable enough for examination. If the silver chloride paper after exposure is fumed with the vapor of burning phosphorus in a closed chamber the writing becomes visible. Solio or similar paper, after contact with faded writing, will show an image if mercury be poured on it from a height of about 30 cm. and the paper be immersed in dilute ammonia. The paper after contact may also be exposed 15 minutes to direct sunlight and then pressed against a dry plate, which can subsequently be developed with dilute rodinal. If the manuscript be dampened a weak solution of hydrogen peroxide will often assist.

Some Properties of Industrial Electrolytic Iron. L. GUILLET and A. PORTEVIN. (*Compt. Rend.*, clvi, 702.)—The metal on coming out of the electrolyte is saturated with hydrogen and is very hard. When heated for two hours in magnesium oxide it loses a great part of its hardness. The critical points obtained by heating are 791° and 937° ; those obtained by cooling are 902° and 778° . The critical points of heated metal are practically the same. In the crude metal there is an absorption of heat at 530° and 590° , which points do not appear on cooling or reheating, being evidently due to the presence of hydrogen. Conductivity tests on raw iron give 10.22 microhms, while the treated metal gives a value of 11.92 microhms, these abnormally high values being due to hydrogen in the metal.

Action of Various Substances on Concrete. R. K. MEADE. (*J. Ind. Eng. Chem.*, v, 723.)—Experiments with test briquettes prepared from cement-sand (1 : 13) mixtures are described, which show that the addition of barium compounds or iron compounds (red brick dust, etc.) is ineffective for preventing or appreciably retarding the disintegrating action of magnesium salts and sulphates on concrete. Disintegration is retarded somewhat by application of various waterproofing materials, especially lime soap and lime soap and alum. Cements of low alumina-content withstand the action of magnesium sulphate solution much better than those containing a larger quantity of alumina. Experiments with mineral oils showed that no destructive action is likely to take place where cement is used for floors in machine shops and engine-rooms.

The Chemistry of Boiler Scale Prevention. EDGAR T. WHERRY and GEORGE S. CHILES. (*Eng. Mag.*, xlv, 518.)—Many substances are used to prevent boiler scale. According to the usual theory, definite reactions must occur between these and the calcium and magnesium salts in the water to produce any effect. The results obtained in practice do not confirm this view, either in that the substances used are often incapable of causing such reactions, or the amounts necessary are much less than would be required. When the calcium and magnesium compounds first separate from the water they are colloidal, and their hardening to form scale is due to their becoming crystalline. Protective colloids might be expected to prevent this change, and it is pointed out that most of the substances used are capable of acting in this capacity.



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EFFECT OF ELECTRICAL ENGINEERING ON MODERN
INDUSTRY.*

BY

CHARLES P. STEINMETZ, M.A., Ph.D.,

Professor of Electro-physics, Union College; Chief Consulting Engineer,
General Electric Company.

I.

THE use of electricity in modern civilized life is rapidly increasing: in lighting our homes, factories, streets; in industrial power applications; in domestic service, from the fan motor to the electric bell or the heating and cooking device; in transportation: while no great inroads have yet been made into the field of the steam locomotive, an entire system of electric railroads has sprung up all over the country, fully comparable in size and power demand with the steam railway system; large new industries have developed in electro-chemistry and electro-metallurgy, supplying us with materials unavailable before—as aluminum—or improving the production of other materials—as copper refining, etc.

All these applications are uses of *energy*. In nearly all, electrical energy is replacing some other form of energy used heretofore: chemical energy of fuel, or mechanical energy of steam or gas engines, etc.

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To understand the reasons which enable electrical energy to compete successfully with other forms of energy, which are longer and more familiarly known, we have to look into its characteristics.

Electrical energy can be transported—or, as we usually call it, transmitted—economically over practically any distance. Mechanical energy can be transmitted over a limited distance only, by belt or rope drive, by compressed air, etc.; heat energy may be carried from a central steam heating plant for some hundred feet with moderate efficiency, but there are only two forms of energy which can be transmitted over practically any distance,—that is, which in the distance of transmission are limited only by the economical consideration of a source of energy nearer at hand: electrical energy, and the chemical energy of fuel. These two forms of energy thus are the only competitors whenever energy is required at a place distant from any of Nature's stores of energy. Thus, when in the study of a problem of electric power transmission we consider whether it is more economical to transmit power electrically from the water power or the coal mine, or generate the power by a steam plant at the place of demand, both really are transmission problems, and the question is whether it is more economical to carry energy electrically over the transmission line, or to carry it chemically, as coal by the railroad train or boat, from the source of energy supply to the place of energy demand, where the energy is converted into the form required, as into mechanical energy by the electric motor or by steam boiler and engine or turbine.

Electrical energy and chemical energy both share the simplicity and economy of transmission or transportation, but electrical energy is vastly superior in the ease, simplicity, and efficiency of conversion into any other form of energy, while the conversion of the chemical energy of fuel into other forms of energy is difficult, requiring complicated plants and skilled attendants, and is so limited in efficiency as to make the chemical energy of fuel unavailable for all but very restricted uses: heating, and the big, high-power steam plant. Pressing the button turns on the electric light and thereby starts conversion into radiating energy: with chemical energy as source, either special fuels are required—in the candle, kerosene lamp—or a complex gas plant. Closing the switch starts the motor, whether a small fan motor, or a 1000-

horsepower motor supplying the water system of a city or driving the railroad train. With fuel as source of energy, boiler plant, steam engine, or turbine, with its numerous auxiliaries, with skilled attendants, etc., are necessary, and the efficiency is low except in very large units. To appreciate the complexity of the conversion of the chemical energy of fuel, compared with the simplicity of electrical energy conversion, imagine the domestic fan motor with coal as source of energy: a small steam engine, with boiler and furnace, attached to the fan: to start the fan, we have to make a coal fire and raise steam to drive the engine. This illustrates how utterly unavailable the chemical energy of fuel is for general energy distribution. General energy distribution, therefore, may justly be said to date from the introduction of electric power.

Equally true is the reverse: the conversion of mechanical or other energy into electrical is simple and economical, while the conversion into chemical energy is not. Hence, one of the two large sources of Nature's energy, the water power, was, before the days of electrical engineering, useless except to a very limited extent, since the location of the water power is rarely such that the energy could be used at its source. The water powers thus have really been made available only by the development of electrical transmission.

Characteristic of electrical energy is that it can be concentrated to an energy density higher than any other form of energy, and results can thus be produced by it which no other form of energy can bring about, or things done directly by the brute force of energy, as we may say, which formerly had to be brought about in a roundabout way.

Thus iron can be reduced from its ores by the chemical energy of coal in the blast furnace, but aluminum and calcium can not, as their chemical affinity is higher, and require the higher energy concentration available with electric power. Iron reduced in the blast furnace combines with carbon to cast iron. So calcium combines with carbon in the electric furnace to carbide, the starting material of acetylene, and of cyanamid and the modern fertilizer industry. Platinum can just be melted, and quartz softened, in the hottest flames of combustion: the oxy-acetylene flame and the oxy-hydrogen flame. But in the electric arc platinum and quartz and every existing substance, even tungsten and

carbon, can be melted and distilled or sublimed. Thus mighty industries have grown up and many new materials made available to man, as aluminum, silicon, calcium, chromium, the carbides, cyanamid, acetylene, etc.; others produced in a cheaper manner, as alkalies, hypochlorites, phosphorus, magnesium, sodium, etc.

Electricity as such is the most useless form of energy: it is not found in Nature in industrially available quantities, and finds no industrial use as electrical energy, but it is always produced from some other form of energy, and converted into some other form of energy: light, mechanical energy, chemical energy, heat, etc. That is, electrical energy is entirely the connecting link, the intermediary, by which energy is brought from the place where it is found to the place where it is used, or changed from the form in which it is found to the form in which it is used. Thus, on first sight, it appears a roundabout way, when, for instance, in modern electrical ship propulsion an electric generator is placed on the steam turbine, a motor on the ship propeller, a few feet away, though it is not different from practically every other use of electric energy: a transmission link, superior to any other transmission by the flexibility given by the simplicity and economy of conversion.

The most serious disadvantage of electrical energy is that it can not be stored. It is true, there exists the electric storage battery, and it is used to a large extent as stand-by battery in high-grade electric distribution systems to give absolute reliability of service, or as battery floating on a railway circuit to equalize fluctuations of power, or in special applications, as electric automobiles. It does not really store electrical energy, but stores energy by conversion of the electrical into chemical energy, and reconversion, in discharge, of the chemical into electrical energy.

The economic efficiency of the storage battery—using the term in the broad sense including interest on the plant investment and depreciation—is so low that the storage battery does not come into consideration in the industrial storage of energy,—that is, in making the rate of electrical energy consumption independent of that of energy production. We can best realize this by comparing electrical energy with the chemical energy of fuel: the latter can be stored with perfect economy. Thus, when using fuel as the source of energy—in a steam plant—no serious difficulty is met by the industry even if the fuel supply is interrupted

for months, as in the case of a supply by water, through the closing of the navigation by ice: we would simply bring in a sufficient coal supply to last until the navigation opens again in spring. But with electrical energy from a water power we could never dream of storing energy by storage battery to last over the two or three months during which the river runs dry and the water power fails.

This means that electrical energy must be consumed at the rate at which it is produced, and the cost of electrical energy thereby becomes dependent on the rate of the energy use. This is not the case with most other forms of energy, as, for instance, the chemical energy of fuel. The price of a ton of coal, as determined by the cost of supplying it, is the same whether I dump the coal into a furnace all at once, or whether I use it up at a uniform rate in a small stove, lasting for weeks. If I consume 2400 cubic feet of gas per day, its cost and thereby its price is the same whether I use the gas at a uniform rate throughout the day, of 100 cubic feet per hour, or whether I use the entire 2400 cubic feet in one hour, nothing in the remaining 23 hours: the gas is produced at whatever rate is most economical, stored in the gas holders and supplied from there at whatever rate it is required for consumption. If, however, I use 240 kilowatt-hours of electrical energy per day, it makes a very great difference in the cost of supplying this energy whether I use it at a uniform rate of 10 kilowatt-hours per hour, or whether I use the entire 240 kilowatt-hours in one hour, nothing in the remaining 23 hours. In the former case, 10 kilowatts of generating machinery are necessary in the steam or hydraulic station producing the electric energy, 10 kilowatts capacity in transmission lines, transformers, sub-station and distribution lines, to supply the demand. In the latter case, 240 kilowatts of generating machinery, 240 kilowatts of line and transformer capacity are absorbed, and that part of the cost of supplying the electric energy, which consists of interest in investment in the plant, of depreciation, etc.,—in short, the fixed cost,—is 24 times as high in the latter as in the former case. If the fixed cost approximates half the total cost in a steam plant, or is by far the largest part of the total cost in a hydraulic plant, it follows that in the case of concentrated energy used during a short time the cost of electric energy—and with it the price—will be very much larger—many times, possibly—as in the case of a uniform energy consumption.

Thus, due to the absence of storage, the cost of electrical energy essentially depends on the uniformity of the rate of its use,—that is, on the load factor, as the ratio of the average consumption to the maximum consumption.

If I use 240 kilowatt-hours of electrical energy in one hour, nothing during the remaining 23 hours, that part of the cost which is the fixed cost of plant investment and depreciation is 24 times as great as if I used the same amount of energy at a uniform rate throughout the day. In the former case, if somebody else uses 240 kilowatt-hours, but during another hour of the day, the same plant supplies his energy, and the fixed cost thus is cut practically in two,—that is, the cost of energy to both of us is materially reduced. Thus, again, the cost of electrical energy, and with it its price, depends on the overlap or not overlap of the use of the energy by different users, the so-called “diversity factor.” The greater the diversity factor,—that is, the less the different uses overlap and the more their combination, therefore, increases the uniformity of the total energy demand, the “station load factor,”—the lower is the energy cost. The cost of electrical energy for lighting, where all the demand comes during the same part of the day, is inherently much higher than the cost for uniform 24-hour service in chemical works, and with the increasing variety of load, with the combination of energy supply for all industrial and domestic purposes, the cost of energy decreases.

Thus, unlike other forms of energy, due to the absence of energy storage, electrical energy can have no definite cost of production, but, even supplied from the same generating station, its cost varies over a wide range, depending on the load factor of the individual use and the diversity factor of the different uses.

This feature, of necessity, must dominate the economical use of electrical energy in industrial, domestic, and transportation service.

II.

Civilization results in the complete interdependence of all members of society upon each other. Amongst the savages each individual, family, or tribe is independent, produces everything it requires. In the barbarian state some barter develops, followed by trade and commerce with increasing civilization. But up to a fair state of civilization—up to nearly a hundred years ago—all necessities of life were still produced in the immediate neighbor-

hood of the consumer, each group or territory still independent in its existence, and commerce dealing with such things only which were not absolutely necessary for life. All this has now changed, and in our necessities of life, as well as luxuries, we depend on a supply from distances of hundreds and thousands of miles: the whole world contributes in the supply of our food, clothing, building materials, etc.

That means, our existence is dependent on an efficient and reliable system of transportation and distribution of all needs of civilized life. Such has been developed during the last century in the system of steam railroads, which, in taking care of the transportation and distribution of commodities, have made modern civilization possible. For civilization means separation of production, in time and in location, from consumption, to secure maximum economy.

The necessities of civilized life consist of two groups: materials and energy. Our transportation system takes care of materials, but can not deal with the supply of energy, and the failure of an efficient energy supply has been and still is the most serious handicap which retards the advance of civilization. The transportation system could deal with the energy supply only in an indirect manner, by the supply of materials as carriers of energy, and when our railroads carry coal it is not the material which we need, but the energy which it carries. But this energy is available only to a very limited extent, as heat, and as mechanical power in big steam units; most of the energy demands of civilized life could not be satisfied by it. In any country village far away from the centres of civilization we have no difficulty to have delivered to us any material produced anywhere in the world; but even in the centres of civilization we could not get the energy to run a sewing machine or drive a fan without *electric power*. Thus, just as our steam railways and express companies take care of the transportation and distribution of materials, so civilization requires a system of transmission and distribution of energy, and our electric circuits are beginning to do this; and just as fifty to seventy-five years ago in the steam railroads, steamship lines, etc., the system of transportation and distribution of materials was developed, so we see all around us in the electric transmission systems the development of the system of the world's energy transmission in progress of development. When we see local

electric distribution systems combining, the big electric systems of our capital cities reaching out over the country, transmission lines interconnecting to networks covering many thousands of square miles, this is not merely the result of the higher economy of coöperation, of mass production, but it is the same process which took place in the steam railroad world some time ago, as a necessary requirement of coördination to carry out their function as carriers and distributors of materials in the case of the railroads, of energy in the case of the electric systems.

We must realize this progress, and the forces which lead to it, so as to understand what is going on, and to assist in the proper development, in avoiding, in the creation of the country's electrical network, whatever mistakes have been made in the development of the country's railway network.

Electricity, thus, is taking over the energy supply required by civilization as the only form of energy which, by its simplicity and economy of conversion, combined with economical transmission, is capable of supplying all the energy demands, from the smallest domestic need to the biggest powers. As we now begin to realize, the economic function of the steam engine is not the energy supply at the place of consumption, from the chemical energy of coal—it is too complicated and inefficient for this—but it is the conversion of chemical energy of coal into electrical energy in bulk, for transmission and distribution to the places of consumption.

If, then, electric power takes the place of steam power in our industries, etc., it is not merely the substitution of the electric motor for the steam engine or turbine. Such would rarely realize the best economy. The method of operation in all our industries, and especially those requiring considerable power, is largely—more than usually realized—determined by the characteristics of the power supply, and what is the most economical method with the steam engine as source of power may be very uneconomical with electric power supply, and electric power supply often permits a far more economical method of operation which was impossible with steam power. Thus the introduction of electricity as the medium of distributing the world's energy demand means a reorganization of our industrial methods, to adapt the same to the new form of power.

For instance, the steam engine requires skilled attendance,

and with its boiler plant, auxiliaries, etc., is a complex apparatus, is economical only in large units. Thus, when operating a factory or mill by steam power, one large engine is used, driving by shafts and counter-shafts, by pulleys and belts, and possibly wasting half or more of its energy in the mechanical transmission to the driven machines. But we could not economically place a steam engine at every one of the hundreds of machines in the factory. Substituting electrical power by replacing the engine by one large electric motor would be very uneconomical, as we can place a motor at every driven machine, and these small motors are practically as efficient—within very few per cent.—as one big motor would be, and all the belting and shafting, with its waste of energy, inconvenience, and danger, vanishes. With the steam engine as source of power, to run one or two machines only, to complete some work, requires keeping the big engine in operation, and therefore is extremely wasteful. With individual electric motors the economy is practically the same, whether only one or two motors are used, or the entire factory is in operation. On the other hand, with the steam engine, it makes no difference in the cost of power whether it is in operation from 8 A.M. to 6 P.M., or from 6 A.M. to 4 P.M. With electric power, in the former case the power demand would overlap with whatever lighting load the same supply circuit carries, but would not in the latter case, and the latter case thus would give a better load factor of the electric circuit, and thereby a lower cost of power. Again, with electric power, if very large power demands could be restricted to the periods of light load on the electric supply systems, this would reduce the cost of power. Nothing like this exists with the steam engine.

Electrical energy thus makes the power users economically more dependent upon each other, and thereby exerts a strong force toward industrial coördination,—that is, coöperation.

Another illustration of the industrial reorganization required to derive the full benefit of electric power is afforded by the traction problem. Very often a study of the electrification of a railway shows no economical advantage in the replacement of the steam locomotive by the electric locomotive, even when considering only passenger service. At the same time, an electric railway may parallel the same steam railway, offer better service at lower price, and show financially better returns than the steam

railway. But so, also, in the early days of steam, the steam engine in place of the horse in front of the stage coach was no success, and still the stage coach has gone and the steam locomotive has conquered; but it did not by replacing the horse, but by developing a system suited to the characteristics of the steam engine. The same repeats now in the relation of steam traction and electric traction. The steam engine is most economical in the largest units, and the economy of steam railway operation depends on the concentration of the load in as few and as large units as possible: therefore, the largest locomotive which can pass through bridges and around curves. Exactly the reverse is the condition of economy of electric traction: the economy depends on the distribution of the load as uniformly as possible in space and in time,—that is, small units at frequent intervals,—and therefore, while steam traction has gone to larger and larger units, in electric traction even the trailer car, so frequently used in the early days, has practically vanished. Obviously, then, the electric motor can not economically compete with the steam engine under the conditions of maximum economy of steam and minimum economy of electric operation, and electric traction under steam traction conditions shows marked economy only in the case of such heavy service that the maximum permissible train units follow each other at the shortest possible intervals,—that is, give maximum uniformity of load,—and thus the economic requirements of both forms of power coincide. These two instances may illustrate the changes in industrial operation which the introduction of electric power requires and which are taking place to-day.

To conclude, then: Electric energy is the only form which is economically suited for general energy transmission and distribution. Civilization depends on the supply of materials and of energy as its two necessities. The supply of materials is taken care of by the transportation system of the world. The supply of energy is being developed by the electrical transmission system, which with regard to energy becomes what the railway system is with regard to materials. Introduction of electric power in place of other forms of power rarely can be a mere substitution, but usually requires a change of the methods of power application, a reorganization of the industry, to secure maximum economy.

THE SKIN EFFECT AND ALTERNATING-CURRENT RESISTANCE.

BY

EDWIN F. NORTHRUP, Ph.D.,

Member of the Institute.

WITH MATHEMATICAL TREATMENT BY

JOHN R. CARSON.*

I. SKIN EFFECT AND ALTERNATING-CURRENT RESISTANCE AS CLOSELY-RELATED PHENOMENA.

THE "skin effect" and alternating-current resistance (terms which we shall later define with care) are such closely-related phenomena that they cannot be adequately investigated, either mathematically or experimentally, the one apart from the other. We are therefore treating both these phenomena in the one paper.

In a conductor (maintained at a uniform temperature throughout its cross-section) which carries a direct current of uniform intensity, the current distributes itself with strictly uniform density over the cross-section of the conductor. This is the only distribution in which the rate of heat production is a minimum and it may be proved ¹ that in the case of steady currents the distribution of the currents will always be such as to make the rate of heat production as small as possible. When, however, the impressed electromotive force becomes variable, alternating or oscillating, new forces arise which may change the current distribution over

* To E. F. Northrup is due the initiation of the investigation herein recorded, the planning of the research, the experimental methods employed, and the physical treatment of the ideas and facts recorded; to Mr. John R. Carson, of the Department of Electrical Engineering of Princeton University, are wholly due the mathematical investigation and the writing of Section IV, with the curves exemplifying the formulæ obtained by him; Mr. Dudley Sanford and Mr. R. J. Kieffer, graduate students in electrical engineering in Princeton University, made all the experimental observations at the writer's request and under his immediate supervision, and prepared a report upon the work, which is in part here reproduced.

¹ "Elements of Electricity and Magnetism," paragraphs 194, 195, by J. J. Thomson.

the cross-section of the conductor in a way not at all consistent with the above principle. The phenomena of the current flow may assume great complexity. In certain cases of conductors of non-magnetic material, the current distribution over the cross-section of the conductor and the rate of heat production in the conductor can be calculated to an approximation which will meet any ordinary engineering requirements. In conductors of ferrous material, however, the phenomena assume a complexity beyond the power of any analysis to specify—except in so far as to reveal the general trend of the phenomena. The alternating-current resistance in such cases can only be determined precisely by experimental investigation.

The general effect of a variable impressed electromotive force is to cause a distribution of the resulting current such that the current density is greater near the circumference than near the axis of the conductor. As the entire cross-section of the conductor does not equally share in the carrying of the current, the total heat production in the conductor will not be the same as would be given by a uniform distribution of the current. Hence the alternating-current resistance is a different and larger quantity than the direct-current resistance.

While direct-current resistance is only a function of the nature of the material and temperature (when reduced to unit section and unit length), alternating-current resistance, on the other hand, is a function of many variables, and is especially complicated to consider in conductors of magnetic material. In the latter case it not only varies with the specific ohmic resistance of the material, the temperature, the section, and the frequency, but with the current and the permeability, this itself varying in a complex manner, over the cross-section of the conductor.

As this paper will show, the skin effect and the alternating-current resistance may assume large magnitudes in important cases which arise in engineering practice. It becomes, therefore, important to investigate, to measure, and to clearly describe (as best we may) these phenomena. As, in the writer's opinion, every mathematical investigation should be preceded by a physical consideration of the matter under investigation, we shall proceed in this way; and, following Mr. Carson's analysis, we shall give the experimental results which were obtained and some obvious deductions and suggestions to which one is naturally led.

II. CURRENT DISTRIBUTION; GENERAL STATEMENT AND ASSUMPTION.

In the case of a metallic conductor of circular cross-section, the statement that direct-current distributes itself uniformly over the cross-section is based upon the assumption that the temperature is uniform over the area of the section or upon the assumption that the material of the conductor is without a temperature coefficient. Now it is apparent that, if the current is sufficiently large to heat the conductor, the conductor losing heat from the surface will tend to become cooler at its surface than at its axis. This being so, the circumferential layers will have a lower resistivity than the axial portion, and hence the current will crowd toward the circumference, more so as the tendency to a temperature gradient from axis to circumference is increased. In the case of copper conductors of large circular cross-section made to carry direct currents which heat them considerably, a marked increase in current density at the circumference over the current density of the axis would undoubtedly occur. Thus an imitation of the skin effect may occur with direct currents. If the temperature of the surface of the conductor is registered with a thermocouple, and if this is called the temperature over the cross-section of the conductor, an apparent departure from Ohm's law would be observed in measuring the ohmic resistance, if the current used is such as to heat the conductor. In all mathematical treatments of direct-current flow such influences are ignored, though delicate measurements would surely reveal them.

When the current is alternating, the axial portion of the conductor is cut by a greater number of the expanding and contracting lines of induction than the circumferential portion. As a result of this, back electromotive forces are set up in the axial portion, and the current crowds towards the circumference, where it is least opposed by these back electromotive forces. If the temperature of the conductor is assumed uniform over its cross-section, and if the permeability of its substance is unity or is assumed constant, then it is possible to derive formulæ which precisely express the current density over the cross-section, the phase relations of the current elements in respect to each other at different points along the radius of the conductor, and the increase in the resistance of the conductor produced by the altered current

distribution. But for a precise expression or statement of what actually takes place neither of the above assumptions can be made. The current when crowded to the circumference (in the case of non-magnetic material with a temperature coefficient) will heat the circumferential portion. This heating will increase the resistance at this place and there will be a temperature gradient, too complicated to express, from axis to circumference which will modify the calculated current distribution. Of course, effects of this character must be small in the case of ordinary conductors used in power transmission, but in the case of the short, heavy conductors used for supplying large-capacity electric furnaces they may doubtless become considerable. In the case of large conductors of ferrous material, the assumption of a constant permeability from axis to circumference is so far from the truth that a mathematical analysis of the alternating-current resistance must and did entirely fail to predict phenomena of magnitude and real engineering importance. One important unpredicted phenomenon, which experiment revealed, is that the alternating-current resistance in ferrous materials reaches a sharp maximum with increasing current and then declines with an asymptotic curve (see curves, etc.).

We do not underate the value of analysis in dealing with the skin effect and alternating-current resistance, but wish attention drawn to the fact that the analysis can give no more truth than is put into the original assumptions—which must be made simple in character to make analysis possible. As a mathematical expression cannot give the whole truth, it is well to inquire if simple physical considerations may not yield information which, though also but a part of the truth, may nevertheless meet many of the engineering requirements besides giving clearness and vividness to the character and general trend of these very complex phenomena. We proceed to our conception of the physical aspect of the skin effect and alternating-current resistance.

III. PHYSICAL VIEW OF SKIN EFFECT AND ALTERNATING-CURRENT RESISTANCE.

Non-magnetic Material; Solid Conductor.

To simplify our considerations assume: That the conductor is circular in cross-section and very long; that the return con-

ductor is a hollow cylinder of infinite conductivity which closely fits the outgoing solid conductor, being insulated from it by very thin insulation; that its resistivity ρ is known and constant; that the frequency n and the total current I are invariable, and that the latter when alternating is of pure sine wave form. Assume further that the electrostatic field of force between the outgoing and return conductors in nowise affects the problem; that all calculations apply to a unit length of the conductor, and that over the cross-section of this unit length the impressed electromotive force per unit length of the conductor is strictly uniform.

The references are to Fig. 1, and the calculations are in C.G.S. units. Call G the radius of the conductor and g the distance measured along the radius from the axis to any point p within the conductor. When direct current of value I flows through the conductor the intensity of the magnetic force at any point p within the conductor is

$$T_g = \frac{2I_g}{G^2} \dots\dots\dots (1)$$

Thus the field increases uniformly from 0 at the axis to $\frac{2I}{G}$ at the circumference.

Curve I, Fig. 1, shows the intensity of the field at each point along the radius. The area of the triangle oab is $\frac{1}{2} G \times \frac{2I}{G} = I$, and is numerically equal to N , the total number of lines of force in the interior of the conductor.²

Consider a single annulus of the conductor which has a radius g and a radial width dg , and that the point p , Fig. 1, is located in this annulus. It is evident, when by the establishment of the current the number of lines of force increases from 0 to N , that as many lines of force cut this annulus as lie in the space between the point p and the circumference of the conductor; namely, by a number proportional to the area $pqab$. Thus for any other point on the radius the number of lines of force which cut an annulus passing through the point will be proportional to that part of

² Maxwell, "Electricity and Magnetism," paragraph 682, or consult "Some Newly Observed Manifestations of Forces in the Interior of an Electrical Conductor," by Edwin F. Northrup, *Phys. Rev.*, June, 1907.

the area of the triangle *oab* which lies between the point and the circumference of the conductor. The expression for this portion of the area of the triangle is

$$N_p = \frac{G^2 - g^2}{G^2} = I \dots\dots\dots (2)$$

where *I* is the maximum value of the total current.

If the current, which gives rise to the lines of force, alternates as a sine wave with a frequency *n*, the annulus will be cut by *N_p* lines of force four times in each complete cycle: once with expanding lines of force and once with contracting lines of force, the current having a positive direction, and once with expanding and once with contracting lines of force, the current having a negative direction. Hence an electromotive force will be induced in the annulus parallel to the axis of the conductor, and the average value of this electromotive force will be:

$$E_{avg} = \frac{4\pi n (G^2 - g^2)}{G^2} I \dots\dots\dots (3)$$

Since the maximum value of the current is $\frac{\pi}{2}$ times the average value *I_{avg}*,

$$E_{avg} = \frac{2\pi n (G^2 - g^2)}{G^2} I_{avg} \dots\dots\dots (4)$$

and since the average value of the electromotive force bears the same relation to its effective value [namely,

$$E_{avg} = \frac{2\sqrt{2}}{\pi} E_{eff}]$$

as the average value of the current bears to its effective value, we have,

$$E = \frac{2\pi n (G^2 - g^2)}{G^2} I \dots\dots\dots (5)$$

where now we are to understand by *E_b* and *I* effective values of electromotive force and current, both being in C.G.S. electromagnetic units.

If we call $I_d = \frac{I}{\pi G^2}$, the current density of the effective

current on the temporary assumption that the current is uniformly distributed over the cross-section of the conductor, the value of the effective induced electromotive force becomes:

$$E_b = 2\pi^2 n (G^2 - g^2) I_d \dots\dots\dots (6)$$

By E_b we are to understand the induced electromotive force per unit length of the conductor at all points distant g from the axis, and which in general will differ in value and phase from both the impressed electromotive force and the electromotive force consumed by ohmic resistance. The electromotive force consumed by ohmic resistance will be equal to the product of the resistivity ρ of the material and the current density, or

$$E_f = \rho I_d \dots\dots\dots (7)$$

This electromotive force will have the same phase as the current, and it will be in quadrature with the induced electromotive force at any annulus of radius g . The impressed electromotive force, E_i (which is uniform in magnitude and phase over the cross-section of the conductor), is the vectorial sum of E_f and E_b , or

$$E_i = \sqrt{E_f^2 + E_b^2} \dots\dots\dots (8)$$

From equations (6), (7), and (8) we obtain,

$$I_d = \frac{E_i}{[\rho^2 + 4\pi^4 n^2 (G^2 - g^2)^2]^{1/2}} \dots\dots\dots (9)$$

The direct-current density when the direct impressed electromotive force is E_i is

$$I_d^1 = \frac{E_i}{\rho} \dots\dots\dots (10)$$

The ratio

$$\frac{I_d^1}{I_d} = \sqrt{1 + \frac{4\pi^4 n^2}{\rho^2} (G^2 - g^2)^2} \dots\dots\dots (11)$$

With the assumption made that the distribution of the lines of force over the cross-section of the conductor is that which would exist if the current were uniformly distributed over the cross-section, equations (5), (6), (9), and (11) are true equa-

tions. In Fig. 1, curve V is a plot of equation (6) where $G = 1$ cm., $n = 100$ cycles, and $I_d = \frac{12.5}{\pi} = 3.979$. (Note that this curve has the same form as the curve which expresses the hydrostatic pressure in the interior of a conductor carrying a uniformly distributed current.)³

Curve VI is a plot of equation (9) in which the values chosen for the constants are, $E_i = 1$, $\rho = 96 \times 10^3$ (the approximate specific resistance of mercury in C.G.S. units), $n = 7072$ cycles, and $G = 1$ cm. By the nature of the assumption made above, curves V and VI can only give an approximation to the truth. As curve VI shows, the current distributes itself more densely toward the circumference, and the magnetic field is no longer distributed as it is with uniform current distribution in the manner given by curve I. If all the current were flowing in that portion of the conductor which forms a cylinder of internal radius d and external radius G , then the distribution of the magnetic field may be obtained from the equation,

$$T_c = 2 I \frac{g^2 - d^2}{(G^2 - d^2) g} \dots\dots\dots (12)$$

Calling $d = \frac{G}{2}$, we obtain

$$T_c = 2 I \frac{4g^2 - G^2}{3 G^2 g} \dots\dots\dots (13)$$

Curve III is a plot of equation (13) in which $G = 1$ and $I = 12.5$. Here the area of the figure *pab* gives the total number of lines of force in the cylinder when the current in the cylinder is I . It will be noted that these lines are very much less in number than the lines N_p [equation (2)]. Hence it follows that when the skin effect has begun to manifest itself and the current is crowded toward the circumference, the tendency to a further crowding of the current toward the circumference is diminished.

³ "Some Newly Observed Manifestations of Forces in the Interior of an Electric Conductor," by Edwin F. Northrup, *Phys. Rev.*, June, 1907, p. 487, Eq. (6).

* *Ibid.*, p. 479, Eq. (3).

We conclude, therefore, that the true curve which expresses the current density at different points along the radius of the conductor must be flatter, and never steeper, than the curve obtained in the manner of curve VI drawn upon the assumption of a field of force disposed as given by uniform current distribution.

In curve VI, the ratio of the current density at the circumference to the current density at the axis is $\frac{10.43}{5.92} = 1.760$. It is shown by the analysis in Section IV that the true ratio of the current density at the circumference to the current density at the axis, when the same constants are used, is 1.50.

It is now possible to calculate the ratio of the alternating-current resistance to the direct-current resistance with the aid of graphical constructions and to obtain a fairly close approximation to the true value of this ratio. By definition the alternating-current resistance is

$$R_{ac} = \frac{\text{total watts developed per unit length}}{\text{square of total current}},$$

and the direct current resistance is $R_{dc} = \frac{\rho}{\pi G^2}$.

Let $R_{ac} = \frac{W}{I_t^2}$, where W = total watts per unit length and I_t = the total current.

$$\frac{R_{ac}}{R_{dc}} = \frac{\pi G^2}{\rho} \cdot \frac{W}{I_t^2}. \quad \text{Let the conductor be of unit radius.}$$

$$\text{Then } G = 1 \text{ and } \frac{R_{ac}}{R_{dc}} = \frac{\pi}{\rho} \cdot \frac{W}{I_t^2}. \quad \dots\dots\dots (14)$$

(a) To obtain I_t^2 .

Let the impressed electromotive force per unit length = 1.

Then by Equation (9) when $G = 1$,

$$I_d = \frac{1}{\sqrt{\rho^2 + 4\pi^4 n^2 (1 - g^2)^2}} \dots\dots\dots (15)$$

If we plot the curve for I_d , letting $\rho = 96 \times 10^3$ and $n = 7072$, we obtain curve VI.

If all the ordinates of curve VI are multiplied by $2\pi g$, curve VII is obtained. If any ordinate of this curve is multiplied by dg , we obtain the current which is flowing in an annulus of radius

g and radial width dg . The current, however, in each annulus will have a different phase. The phase of the current, in respect to the impressed electromotive force, flowing in any annulus of radius g is given by the relation,

$$\tan \omega = \frac{2\pi^2 (1 - g^2) n}{\rho} \dots\dots\dots (16)$$

Thus the phase of the current changes continuously from the axis to the circumference, being $\tan \omega = \frac{2\pi^2 n}{\rho}$ at the axis and $\tan \omega = 0$ at the circumference. With the constants and the method of calculation we have chosen, the current at the axis lags behind the impressed electromotive force $55^\circ 29'$. The actual angle of lag (using the same constants) as obtained by the analytical method of Section IV is 70° . Since the currents which flow in the annuli of different radii have different phases, the value of the total current cannot be obtained by algebraic addition. Hence the area of curve VII does not give the total current. The addition of the currents in all the annuli must be made vectorially. This vectorial addition may be made as follows:

Find values of $\tan \omega = \frac{2\pi^2 n}{\rho} (G^2 - g^2)$ when g is varied from

0 to G . As we have taken $G = 1$, values of the tangent may be found for eleven values, as 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0. From a table of tangents obtain the corresponding values of ω . From a table of cosines find the corresponding values of $\cos \omega$, and from a table of sines find the corresponding values of $\sin \omega$. Multiply the ordinates of a curve corresponding to curve VII by the cosine values. The ordinates when so multiplied give the components of the current in phase with the electromotive force consumed by ohmic resistance. Hence if we plot a new curve in which the ordinates of curve VII $\times \cos \omega$ are ordinates and values of g are abscissæ, the area which lies between this curve and the horizontal axis is equivalent to the integral

$$A_{\cos \omega} = 2\pi \int_0^{G=1} I_d \cos \omega g \cdot dg$$

$A_{\cos \omega}$ is the component of the total current in phase with the electromotive force consumed by ohmic resistance. The area of

this curve is readily obtained by adding 11 evenly-spaced ordinates and dividing by 11, and multiplying by G , in this case by unity.

Next plot a curve where the ordinates of curve VII $\sin \omega$ are made ordinates and values of g are made abscissæ. The area which lies between this curve and the horizontal axis is equivalent to the integral,

$$A_{\sin \omega} = 2\pi \int_0^{G=1} I_d \sin \omega g dg$$

and is equal to the component of the total current which is in quadrature with the electromotive force consumed by ohmic resistance.

The square of the total current is now

$$I_t^2 = A_{\sin \omega}^2 + A_{\cos \omega}^2 \dots\dots\dots (17)$$

In performing these operations it is not necessary to actually plot any of the curves. One may operate upon the numerical values as if they were actually plotted. These operations when performed for the illustrative example in which $G=1$, $n=7072$, and $\rho=96 \times 10^3$ give

$$A_{\sin \omega}^2 = 127.7 \times 10^{-12},$$

$$A_{\cos \omega}^2 = 532.2 \times 10^{-12}; \text{ and hence}$$

$$I_t^2 = 659.9 \times 10^{-12}.$$

(b) To obtain W :

If all the ordinates of curve VI are squared and multiplied by ρ , we obtain the watts per cubic centimetre at each point along the radius. If after these ordinates are squared and multiplied by ρ we then multiply each product by $2\pi g$, we shall obtain a curve the area between which and the horizontal axis is equal to W .

Let $B' = W$ be the area so obtained. If all the ordinates of curve VI are squared and then multiplied by $2\pi g$ only, we shall obtain a curve the area between which and the horizontal axis will be B where $B' = B\rho$. Curve VIII, Fig. 1, is such a curve.

We now obtain for the ratio of the alternating-current to the direct-current resistance

$$\frac{R_{ac}}{R_{dc}} = \frac{W}{I_t^2} \cdot \frac{\pi}{\rho} = \frac{\pi B}{I_t^2} = \frac{\pi B}{A_{\sin \omega}^2 + A_{\cos \omega}^2} \dots\dots\dots (18)$$

In the illustrative example, the value found for B is 229×10^{-12} , and hence for this particular case

$$\frac{R_{ac}}{R_{dc}} = \frac{3 \cdot 1416 \times 229 \times 10^{-12}}{659.9 \times 10^{-12}} = 1.090.$$

This value is too small by 6 per cent., the true value being 1.160.

The explanation of the discrepancy is interesting. The graphical method of calculation is based upon our original assumption that the field of magnetic force has the distribution in the interior of the conductor which would result from current uniformly distributed over the cross-section of the conductor. The effect of this assumption is to give a greater ratio of the current density at the circumference to the current density at the axis than would actually exist. It will also cause the calculated values, at different points along the radius, of the angle of lag of the current to be too small. This will be understood if we note that the angle of lag of the current at the axis behind the current at the circumference is determined not by the actual number of lines of force which cut any two annuli lying between axis and circumference, but by the proportionate number which cuts the two annuli. Now if the field distribution is that due to uniform current distribution, a smaller percentage of lines will cut the inside annulus as compared with those which cut the outside annulus than will be the case if the field is that due to current having an increasing density toward the circumference.

Again, if we note that the tangent of a phase angle is proportional to self-induction divided by resistance, we have $\tan \omega \propto \frac{L}{\rho}$

Also, $L \propto \frac{\text{flux}}{I_d}$. Now we have assumed I_d , the current density

at the axis greater than it really is after the skin effect has begun

to manifest itself. This assumption makes L and hence $\tan \omega$ too small. As stated above, at the axis we found $\omega = 55^\circ 29'$, whereas it is 70° .

Since in calculating the value of the total current we take products of current densities (which are too large) by cosines and sines of phase angles (which are too small), the errors, due to the nature of the fundamental assumption made, partially neutralize.

As a result we find the ratio $\frac{R_{ac}}{R_{dc}}$ too small, but only by 6 per cent.

We may calculate the ratio $\frac{R_{ac}}{R_{dc}}$ by taking the ratio of the watts being consumed for any instantaneous value of the current to the square of the integral value of the instantaneous current in phase with the electromotive force consumed by ohmic resistance. To perform this calculation we proceed as follows: Multiply all the ordinates of curve VI for the current density by the cosine of the phase angle. Square these values and multiply by $2\pi\rho g$. Plot the resulting curve and take its area. This area will equal the total watt consumption at a given instant. Let this instant be when the current has zero phase at the circumference. Now find, by the procedure given above, the component of the total current in phase with the electromotive force consumed by resistance. Square this component. Divide the first result by the second and multiply by $\frac{\pi}{\rho}$, the reciprocal of the direct-current resistance.

The result is the required ratio.

Expressed analytically:

$$\frac{R_{ac}}{R_{dc}} = \frac{2\pi\rho \int_0^{G=1} (I_d \cos \omega)^2 g dg}{\left[2\pi \int_0^{G=1} I_d \cos \omega g dg \right]^2} \frac{\pi}{\rho}$$

OR

$$\frac{R_{ac}}{R_{dc}} = \frac{\int_0^{G=1} (I_d \cos \omega)^2 g dg}{\left[2 \int_0^{G=1} I_d \cos \omega g dg \right]^2} \dots\dots\dots (19)$$

This calculation was made for the illustrative example chosen and the result was :

$$\frac{R_{ac}}{R_{dc}} = \frac{581 \times 10^{-12}}{532.2 \times 10^{-12}} = 1.092,$$

which is the result obtained by the first method within the error of the numerical calculations.

Magnetic Material; Solid Conductor.

If the conductor consists of iron, the phenomena are profoundly modified both in magnitude and character. The lines in the interior of the conductor are now lines of induction instead of lines of force, and, due to the large permeability of iron, these lines are very numerous. They are not disposed in any way which can be expressed by an equation, because the permeability μ varies with the intensity of the field, which itself varies from axis to circumference. At any point distant g from the axis of a solid conductor the induction per square centimetre will be

$$B = \mu T_g = \frac{2\mu Ig}{C^2} \dots\dots\dots (20)$$

If we assume that the conductor carries the direct current I and that the permeability curve of the iron is given, then we may calculate the induction at each point along the radius by multiplying the value of the field intensity at each point by the permeability taken from the curve. Curve II, Fig. 1, is a curve of the induction at each point along the radius for a solid conductor of soft iron of 1 cm. radius, when carrying a current of 12.5 electromagnetic units. At the point 0.4 cm. from the axis, the field intensity is 10 C.G.S. units, and, taking the permeability at 1500, the induction is 15,000 lines per square centimetre. From here to the circumference the permeability rapidly decreases, so that the curve becomes greatly flattened. The area included between this curve and the horizontal axis gives the total number of lines of induction in the conductor per unit length, and when the current in the conductor changes from 0 to I the total number of lines of induction which cut any annulus of the conductor is equal to the area which lies between a point on the annulus and the circumference. Thus the annulus passing through the point p (Fig. 1) is cut by the lines

which are equal in number to the area $pgcb$. The tendency for alternating current to crowd toward the circumference of the conductor is increased when the total number of lines of induction which cut any annulus in the interior of the conductor is increased. Now when the total current in the iron conductor is increased the flattening of the curve of induction begins nearer the axis, and hence the proportionate amount of the current which is crowded toward the circumference is decreased. The result is that the alternating-current resistance, instead of continually increasing with increase in current, reaches a maximum and then begins to decrease. For very large total current nearly all the iron of the conductor would approach magnetic saturation and then the skin effect would partake of the same magnitude and character as it would in a conductor of non-magnetic material.

That these conclusions are entirely justified is shown by the experimentally obtained curves given later on.

Curve IV has been drawn to show how the lines of induction would be disposed if the same current I had all become crowded into the portion of the conductor which lies beyond the middle point of its radius. Not only is the curve much steeper than curve II, but the total number of lines equal to the area included between it and the horizontal axis is considerably less than the total number which is equal to the area included between the portion $pgcb$ of curve II and the axis. It is concluded that any formulæ deduced to express the ratio of the alternating-current resistance to the direct-current resistance, when it includes μ assumed constant must be for iron conductors only roughly approximate and cannot have much value. We must, therefore, resort to experiment to determine this ratio.

In any method yet devised for measuring the alternating-current resistance it is necessary to compare the alternating-current resistance of the sample with the alternating-current resistance of a standard and to assume that the alternating-current resistance of this standard is either the same as its direct-current resistance or that its departure from its direct-current resistance can be accurately calculated. Experience and calculation have shown that mercury, because of its small temperature coefficient, large specific resistance, and because of the ease with which the resistance of a column of the liquid may be varied, is the best material to use for a standard.

In the mathematical section of this paper, four curves have been drawn which accurately express the ratio of the alternating current to the direct-current resistance of a column of mercury of circular cross-section. Referring (Fig. 10) to the curve for 60 cycles, it will be observed that this ratio for a column of 10 cm. in diameter is only 1.008 and for one 6 cm. in diameter only 1.001. Hence a column of mercury of this latter diameter could be used for a standard at 60 cycles without correction with an error of only 0.1 of 1 per cent.

From the above physical discussion of the skin effect it plainly appears that any exact mathematical expression for the ratio of the alternating-current resistance to the direct-current resistance must assume the form of an infinite series. We now proceed to the deduction of exact mathematical expressions for this ratio in the case of conductors of circular cross-section.

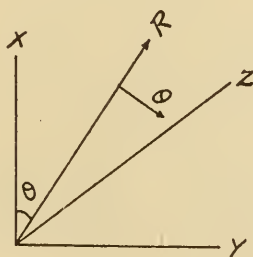
IV. MATHEMATICAL INVESTIGATION OF SKIN EFFECT AND ALTERNATING-CURRENT RESISTANCE.

In the present investigations we shall start with Maxwell's Equations, the basis of modern electromagnetic theory. These equations are the mathematical formulation of two laws:

(1) The line integral of the magnetic force around any closed curve is equal to 4π times the total current flowing through the closed curve.

(2) The line integral of the electric force around any closed curve is equal to the time rate of diminution of the total magnetic induction included by the closed curve.

FIG. 2.



Since we are dealing with electromagnetic effects, propagated along a cylindrical conductor, we shall find it convenient to write our equations in cylindrical coördinates, referred to the axes R ,

θ , and Z . Let the Z axis coincide with the axis of the cylindrical conductor. Then the R and θ axes are in the plane perpendicular of the Z axis; the R axis is radial and the θ axis is tangential, as shown in Fig. 2.

We shall denote the component electric and magnetic forces E and H along the axes Z , R , and θ by the subscripts, z , r , and θ . We shall denote the distance along the vector R from the axis Z by r .

The mathematical formulation of the first law is now:

$$\left. \begin{aligned} \left(4\pi\lambda + K \frac{d}{dt}\right) E_z &= \frac{1}{r} \frac{\delta^*}{\delta z} (rH_\theta) - \frac{1}{r} \frac{\delta}{\delta \theta} (H_R) \\ \left(4\pi\lambda + K \frac{d}{dt}\right) E_R &= \frac{1}{r} \frac{\delta}{\delta \theta} (H_z) - \frac{\delta}{\delta z} (H_\theta) \\ \left(4\pi\lambda + K \frac{d}{dt}\right) E_\theta &= \frac{\delta}{\delta z} (H_R) - \frac{\delta}{\delta r} (H_z) \end{aligned} \right\} \quad (I)$$

λ is the conductivity and K the specific inductive capacity of the medium. All quantities are assumed as expressed in electromagnetic C.G.S. units.

The formulation of the second law gives the three equations:

$$\left. \begin{aligned} -\mu \frac{d}{dt} H_z &= \frac{1}{r} \frac{\delta}{\delta r} (rE_\theta) - \frac{1}{r} \frac{\delta}{\delta \theta} E_R \\ -\mu \frac{d}{dt} H_R &= \frac{1}{r} \frac{\delta}{\delta \theta} (E_z) - \frac{\delta}{\delta z} E_\theta \\ -\mu \frac{d}{dt} H_\theta &= \frac{\delta}{\delta z} E_R - \frac{\delta}{\delta r} E_z \end{aligned} \right\} \quad (II)$$

These equations may be verified by transformation of Maxwell's Equations.

μ is the permeability of the medium.

These general equations are difficult to handle. We shall therefore simplify our work by introducing the assumption that the cylindrical conductor is surrounded by a concentric cylindrical shell of conducting material. The inner and outer conductors are separated by the dielectric. This assumption makes everything symmetrical in planes perpendicular to the axis of Z , and it follows that $E_\theta = 0$ and $\frac{\delta}{\delta \theta} = 0$.

* Partial differentiation

The six equations, I and II, now reduce to :

$$\left(4\pi\lambda + K \frac{d}{dt}\right) E_z = \frac{1}{r} \frac{\delta}{\delta r} (rH_\theta)$$

$$\left(4\pi\lambda + K \frac{d}{dt}\right) E_R = - \frac{\delta}{\delta z} (H_\theta)$$

$$- \mu \frac{d}{dt} H_\theta = \frac{\delta}{\delta z} E_R - \frac{\delta}{\delta r} E_z$$

$$E_\theta = H_R = H_z = 0.$$

That is, the electric force has only two components, one radial and one axial, while there is but one component of magnetic force which is tangential to circles in the $R \theta$ plane, centred on Z axis. Since there is but one component of magnetic force we shall drop the subscript and denote it by H .

We therefore get, writing H for H_θ ,

$$\left(4\pi\lambda + K \frac{d}{dt}\right) E_z = \frac{1}{r} \frac{\delta}{\delta r} (rH) \quad (a)$$

$$\left(4\pi\lambda + K \frac{d}{dt}\right) E_R = - \frac{\delta}{\delta z} (H) \quad (b)$$

$$- \mu \frac{d}{dt} H = \frac{\delta}{\delta z} E_R - \frac{\delta}{\delta r} E_z \quad (c)$$

The foregoing equations express the electric and magnetic force as functions of Z , r , and the time t . If a steady state has been reached, we can, with complete generality, assume that these quantities are harmonic functions of time. Now, instead of taking them as sine and cosine functions of time, let us assume that E_R , E_z and H contain the factor ε^{ipt} where $i = \sqrt{-1}$. Now since

$$\varepsilon^{ipt} = \cos pt + i \sin pt,$$

the expressions for the electric and magnetic forces will be complex quantities. In the final result we ignore the imaginary part and take the real part of the expression as the solution. This is a well-known device in the treatment of differential equations, and enables us to get rid of the explicit appearance of the time in our equations.

If E_R , E_z and H contain the factor ϵ^{ipt} , then

$$\frac{d}{dt} = ip, \frac{d^2}{dt^2} = -p^2$$

We therefore get

$$(4\pi\lambda + Kip) E_z = \frac{1}{r} \frac{\partial}{\partial r} (rH) \quad (1)$$

$$(4\pi\lambda + Kip) E_R = - \frac{\partial}{\partial z} H \quad (2)$$

$$- \mu ip H = \frac{\partial}{\partial z} E_R = \frac{\partial}{\partial r} E_z \quad (3)$$

We have here three simultaneous equations involving E_z , E_R and H . We have to solve for E_z , E_R and H .

Multiplying (1) by $\mu^2 p$, we get

$$(4\pi\lambda\mu ip - Kp^2) E_z = \mu ip \frac{\partial}{\partial r} H + \mu ip \frac{H}{r}. \quad (4)$$

From (3) we have

$$\mu ip H = \frac{\partial}{\partial r} E_z - \frac{\partial}{\partial z} E_R$$

$$\mu ip \frac{\partial H}{\partial r} = \frac{\partial^2}{\partial r^2} E_z - \frac{\partial}{\partial r \partial z} E_R \quad (5)$$

$$\mu ip \frac{H}{r} = \frac{1}{r} \frac{\partial}{\partial r} E_z - \frac{1}{r} \frac{\partial}{\partial z} E_R \quad (6)$$

Substituting (5) and (6) in (4) we get

$$(4\pi\lambda\mu ip - K^2 p^2) E_z = \frac{\partial^2}{\partial r^2} E_z + \frac{1}{r} \frac{\partial}{\partial r} E_z - \frac{\partial}{\partial z} \left\{ \frac{\partial}{\partial r} E_R + \frac{1}{r} E_R \right\} \quad (7)$$

But by Laplace's equations in cylindrical coördinates

$$\frac{\partial}{\partial r} E_R + \frac{1}{r} E_R + \frac{\partial}{\partial z} E_z = 0$$

in a continuous medium.

Equation (7) then becomes

$$(4\pi\delta\mu ip - K\mu p^2) E_z = \frac{\partial^2}{\partial z^2} E_z + \frac{\partial^2}{\partial r^2} E_z + \frac{1}{r} \frac{\partial}{\partial r} E_z \quad (8)$$

Writing

$$(4\pi\lambda\mu_1\rho - K\mu_2) = a^2,$$

$$a^2 E_z = \frac{\delta^2}{\delta z^2} E_z + \frac{\delta^2}{\delta r^2} E_z + \frac{1}{r} \frac{\delta}{\delta r} E_z \quad (9)$$

By exactly analogous methods we get

$$a^2 E_R = \frac{\delta^2}{\delta z^2} E_R + \frac{\delta^2}{\delta r^2} E_R + \frac{1}{r} \frac{\delta}{\delta r} E_R - \frac{E_R}{r^2} \quad (10)$$

Since H is determined by equation (3), if E_z and E_R are known, we shall not solve for H .

We shall solve equation (9) for E_z first and then find the solution of (10) for E_R . Equation (9) is a partial differential equation in r and z . In searching for a solution we shall assume that it is of the form

$$E_z = R \cdot Z$$

when R is a function of r alone, and Z of z alone. Substituting in equation (9) RZ for E_z we get

$$a^2 R \cdot Z = R \frac{\delta^2 Z}{\delta z^2} + Z \frac{\delta^2 R}{\delta r^2} + \frac{Z}{r} \frac{\delta R}{\delta r}, \text{ or}$$

$$\frac{1}{Z} \frac{\delta^2 Z}{\delta z^2} + \frac{1}{R} \frac{\delta^2 R}{\delta r^2} + \frac{1}{rR} \frac{\delta R}{\delta r} = a^2 = \text{constant.}$$

Since the first term can by hypothesis be a function of z alone and the second and third of r alone, we must have

$$\frac{1}{Z} \frac{\delta^2 Z}{\delta z^2} = a^2 - m^2 \quad (11)$$

$$\frac{1}{R} \frac{\delta^2 R}{\delta r^2} + \frac{1}{rR} \frac{\delta R}{\delta r} = m^2 \quad (12)$$

where m is an unknown constant

Writing (11)

$$\frac{1}{Z} \frac{\delta^2 Z}{\delta z^2} = -\beta^2 \quad \text{when} \quad \beta^2 = m^2 - a^2$$

we have as a solution

$$Z = A_1 e^{i\beta z} + A_2 e^{-i\beta z} \quad (13)$$

where A_1 and A_2 are constants of integration.

Equation (12) cannot be integrated as it stands, but by a simple transformation of the independent variable it can be reduced to a standard form. Writing $x = imr$ (12) becomes

$$\frac{\delta^2 R}{\delta x^2} + \frac{1}{x} \frac{\delta R}{\delta x} + R = 0. \quad (14)$$

Equation (14) is a particular case of the general differential equation

$$\frac{\delta^2 R}{\delta x^2} + \frac{1}{x} \frac{\delta R}{\delta x} + \left(1 - \frac{n^2}{x^2}\right) R = 0.$$

The solution of this general equation is a highly convergent infinite series, known as Bessel's Function of the n^{th} order, and denoted by $J_n(x)$. The only two orders we shall have to deal with in the present investigation are the zeroth and the first. These are

$$J_0(x) = 1 - \frac{x^2}{2^2} + \frac{x^4}{2^2 \cdot 4^2} - \frac{x^6}{2^2 \cdot 4^2 \cdot 6^2} + \frac{x^8}{2^2 \cdot 4^2 \cdot 6^2 \cdot 8^2} \dots\dots\dots$$

$$J_1(x) = \frac{x}{2} \left\{ 1 - \frac{x^2}{8} + \frac{x^4}{8 \cdot 24} - \frac{x^6}{8 \cdot 24 \cdot 48} \dots\dots\dots \right\}$$

From Equation (14), we have then

$$R = J_0(x) = J_0(imr) \quad (15)$$

$E_z = R_1 Z$, and we have as our expression for E_z

$$E_z = \{A_1 \varepsilon^{i\beta z} + A_2 \varepsilon^{-i\beta z}\} J_0(imr) \cdot \varepsilon^{ipt} \quad (16)$$

The factor ε^{ipt} is introduced in accordance with our original assumption that all variables contained the factor ε^{ipt} .

Equation (10) for E_R is solved by exactly analogous methods, giving as a solution

$$E_R = \{B_1 \varepsilon^{i\beta z} + B_2 \varepsilon^{-i\beta z}\} J_1(imr) \varepsilon^{ipt} \quad (17)$$

The relations between the constants of integration in the expressions for E_z and E_R are obtained by recourse to Laplace's equation as given above:

$$-\frac{\delta}{\delta z} E_z + \frac{\delta}{\delta r} E_R + \frac{1}{r} E_R = 0$$

If we substitute in the above for E_z and E_R the values given by (16) and (17), and remember that

$$\frac{\delta}{\delta x} J_1(x) = J_0(x) - \frac{1}{x} J_1(x),$$

we get

$$\begin{aligned} & \{i\beta A_1 \epsilon^{i\beta z} - i\beta A_2 \epsilon^{-i\beta z}\} J_0(i\omega r) \\ & + (im) \{B_1 \epsilon^{i\beta z} + B_2 \epsilon^{-i\beta z}\} J_0(imr) = 0. \end{aligned}$$

whence

$$\epsilon^{i\beta z} \{i\beta A_1 + imB_1\} + \epsilon^{-i\beta z} \{-i\beta A_2 + imB_2\} = 0$$

whence

$$\begin{aligned} B_1 &= \frac{-\beta}{m} A_1 \\ B_2 &= + \frac{\beta}{m} A_2. \end{aligned}$$

We therefore have

$$E_z = J_0(imr) \{A_1 \epsilon^{i\beta z} + A_2 \epsilon^{-i\beta z}\} \epsilon^{i\rho t} \quad (16)$$

$$E_R = \frac{-\beta}{m} \left[J_1(imr) \right] \{A_1 \epsilon^{i\beta z} - A_2 \epsilon^{-i\beta z}\} \epsilon^{i\rho t} \quad (18)$$

$$\text{when } im = i \sqrt{a^2 + \beta^2}$$

A complete solution of the problem involves a determination of the exponential constant β which gives the attenuation and phase change of current and electric force along the conductor. β is a function of the dimensions and electrical constants of the inner and outer conductors. For our purpose, however, which is to study the distributions of the current in the inner conductor, we need only know the order of magnitude of β . β is of the order of magnitude of $\left(\frac{\rho}{\lambda V^2}\right)^{\frac{1}{2}}$ where λ is the conductivity of the conductor in electromagnetic units and V is the velocity of light.⁴ Now for the ordinary metals λ is of the order 10^{-4} while V^2 is of the order of 10^{21} . Hence β is of the order of $\left(\frac{\rho}{10^{17}}\right)^{\frac{1}{2}}$.

⁴J. J. Thompson, "Recent Researches."

We have also

$$\begin{aligned} \alpha^2 &= 4\pi\lambda\mu ip - R\mu p^2 \\ \alpha^2 &= p \left\{ 4\pi i\lambda\mu - \frac{p}{V^2} \right\}. \\ &= p \left\{ 4\pi i\lambda\mu - \frac{p}{10^{21}} \right\}. \end{aligned}$$

Therefore for all ordinary metals, unless the frequency runs into the millions of cycles per second, the second term is negligible compared to the first; hence we are justified in writing, when the conductor is a metal,

$$\alpha^2 = 4\pi\lambda\mu ip.$$

But $m^2 = \alpha^2 + \beta^2$. Since β is of the order of magnitude $\left(\frac{p}{10^{17}}\right)^{\frac{1}{2}}$ β^2 is negligible compared to α^2 , and we may write

$$\begin{aligned} m^2 &= \alpha^2 \\ im &= i \sqrt{4\pi\lambda\mu ip}. \end{aligned}$$

Now if we confine our attention to the phenomena occurring at the point $z=0$ in the conductor, as we may do without loss of generality, we have, setting $z=0$ in (16) and (18):

$$\begin{aligned} E_z &= (A_1 + A_2) J_0(imr) \epsilon^{ipt} \\ E_R &= -\frac{\beta}{m} (A_1 - A_2) J_1(imr) \epsilon^{ipt} \quad \text{at } z = 0. \end{aligned}$$

The corresponding current densities, denoted by u_z and u_R are:

$$u_z = \lambda (A_1 + A_2) J_0(imr) \epsilon^{ipt} \quad (19)$$

$$u_R = \lambda \frac{\beta}{m} (A_1 - A_2) J_1(imr) \epsilon^{ipt} \quad (20)$$

Now for ordinary metals we have shown that $\frac{\beta}{m}$ is of the order of 10^{-8} . Hence, unless the reflected wave is nearly equal to the transmitted wave, in which case $A_1 + A_2$ is a small quantity, u_R , the radial or changing current in the conductor, is very small compared to u_z , the current along the conductor, since u_R contains the factor $\frac{\beta}{m}$. Therefore when large currents are transmitted along the conductor, which is the only case for which the current distribution becomes of practical importance, the radial current density u_R is entirely negligible compared to u_z , the current transmitted along the conductor. We shall, therefore, in our subsequent analysis neglect the radial current and the heating

produced by it. The error introduced by our ignoring u_R is so small as to be of theoretical interest only.

Confining our attention to the current density u_z and dropping subscript, we have

$$u = \lambda A J_0 (mr) \varepsilon^{ipt} \dots\dots\dots (21)$$

Now since

$$J_0(x) = 1 - \frac{x^2}{2^2} + \frac{x^4}{2^2 \cdot 4^2} - \frac{x^6}{2^2 \cdot 4^2 \cdot 6^2} + \dots\dots$$

$$J_0(imr) = 1 + \frac{(mr)^2}{2^2} + \frac{(mr)^4}{2^2 \cdot 4^2} + \frac{(mr)^6}{2^2 \cdot 4^2 \cdot 6^2} + \dots\dots$$

But $m = \sqrt{4\pi\lambda\mu ip} = \sqrt{i} \cdot \sqrt{\gamma}$ where $\gamma = \sqrt{4\pi\lambda\mu p}$

Therefore

$$\begin{aligned} J_0(mr) = 1 &- \frac{(\gamma r^2)^2}{(2 \cdot 4)^2} + \frac{(\gamma r^2)^4}{(2 \cdot 4 \cdot 6 \cdot 8)^2} - \frac{(\gamma r^2)^6}{(2 \cdot 4 \cdot 6 \cdot 8 \cdot 10 \cdot 12)^2} + \dots\dots \\ &+ i \left\{ \frac{\gamma r^2}{2^2} - \frac{(\gamma r^2)^3}{(2 \cdot 4 \cdot 6)^2} + \frac{(\gamma r^2)^5}{(2 \cdot 4 \cdot 6 \cdot 8 \cdot 10)^2} \dots\dots \right\} \end{aligned}$$

Also we have

$$\varepsilon^{ipt} = \cos pt + i \sin pt$$

Hence the real part of our solution is gotten by taking the real part of $\lambda A J_0(imr) \varepsilon^{ipt}$ and ignoring the imaginary part. We get, therefore,

$$u = \lambda A \left\{ \begin{aligned} &\cos pt \left[1 - \frac{(\gamma r^2)^2}{(2 \cdot 4)^2} + \frac{(\gamma r^2)^4}{(2 \cdot 4 \cdot 6 \cdot 8)^2} \dots\dots \right] \\ &- \sin pt \left[\frac{\gamma r^2}{2^2} - \frac{(\gamma r^2)^3}{(2 \cdot 4 \cdot 6)^2} + \frac{(\gamma r^2)^5}{(2 \cdot 4 \cdot 6 \cdot 8 \cdot 10)^2} \dots\dots \right] \end{aligned} \right\} \quad (21)$$

This expression for the current density leads to the interesting deduction that not only in magnitude but also in phase the current density is a function of γr^2 . If we set $r = 0$, it follows that $u = \lambda A \cos pt$. Hence λA is the current density at the axis and its phase is $\cos pt$. If we give r a finite value greater than zero, terms containing $\sin pt$ appear, and therefore we see that there is a progressive change of phase, as we go out from the axis of the conductor.

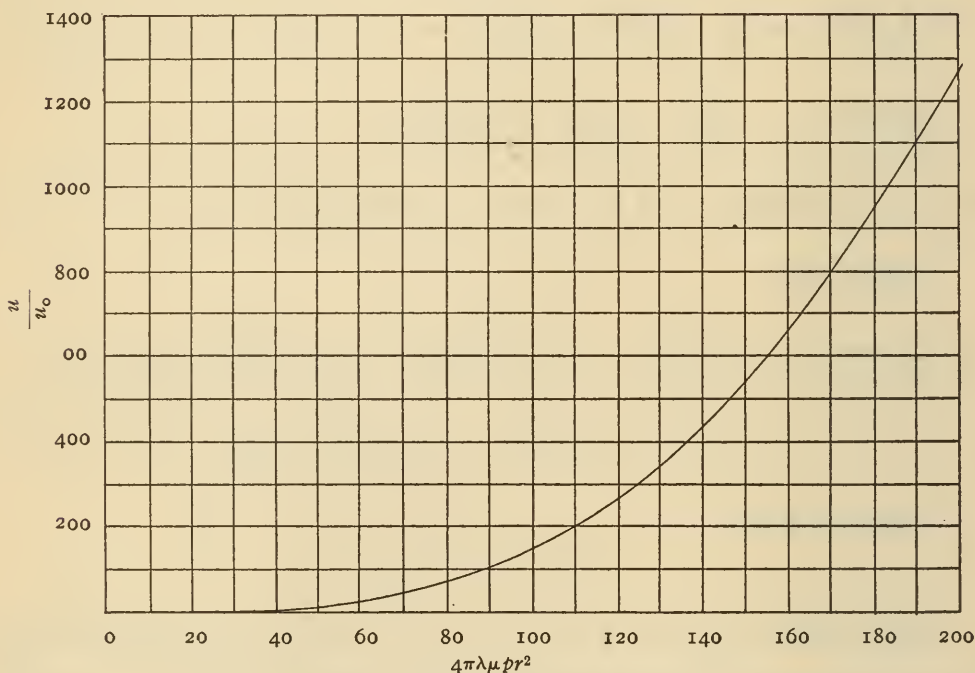
If we write

$$u = u_0 \{ a \cos pt + b \sin pt \}$$

where u_0 is the current density at the axis and a and b are functions of γr^2 , as given by equation (21), the absolute value of the current density is given by

$$|u| = u_0 \sqrt{a^2 + b^2} \dots \dots \dots (21)a$$

FIG. 3.



Curve showing $\frac{\text{current density at circumference}}{\text{current density at axis}}$
for cylindrical conductor.

If θ is the angle of lag of the current density at any distance r from axis, behind current density at axis, then

$$\tan \theta = \frac{b}{a} \dots \dots \dots (21)b$$

In Fig. 3, $\frac{u}{u_0}$ and in Fig. 4, θ are plotted against γr^2 or $4\pi\lambda\mu pr^2$.

So far we have considered the current density u . The total current transmitted is obviously given by

$$\begin{aligned} I &= \text{total current transmitted} \\ &= \int_0^a 2\pi u r dr \text{ when } a \text{ is the radius of the conductor.} \end{aligned}$$

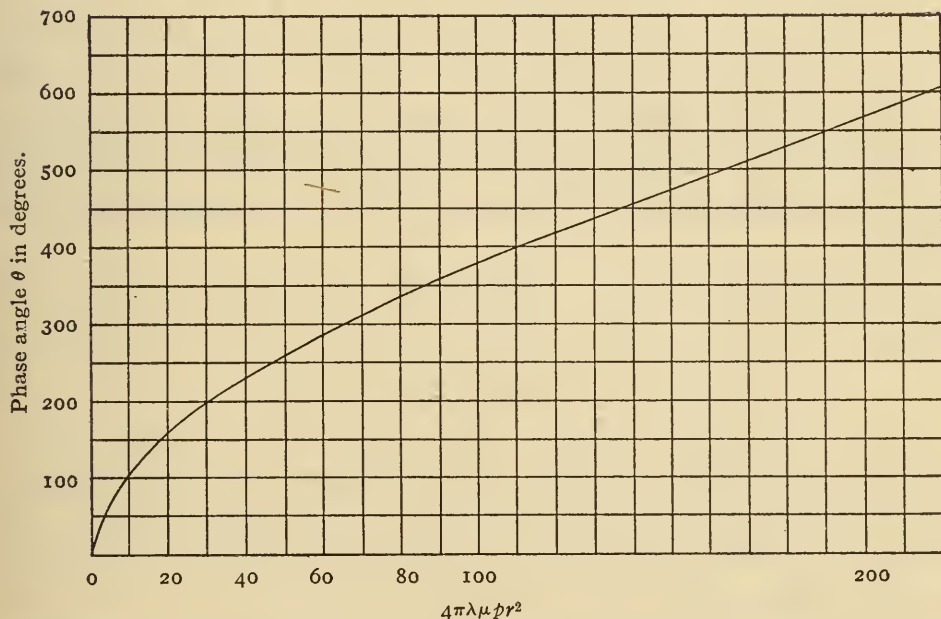
Substituting in our integral the expression for u given by equation (21), we get

$$I = 2\pi\lambda A \left\{ \begin{array}{l} \cos pt \left[\frac{a^2}{2} - \frac{\gamma^2 a^6}{6(2 \cdot 4)^2} + \frac{\gamma^4 a^{10}}{10(2 \cdot 4 \cdot 6 \cdot 8)^2} - \dots \right] \\ - \sin pt \left[\frac{\gamma a^4}{4(2)^2} - \frac{\gamma^3 a^8}{8(2 \cdot 4 \cdot 6)^2} + \frac{\gamma^5 a^{12}}{12(2 \cdot 4 \cdot 6 \cdot 8 \cdot 10)^2} - \dots \right] \end{array} \right.$$

The mean square current, I_m^2 , is given by

$$I_m^2 = \frac{(2\pi\lambda A)^2}{2} \left\{ \begin{array}{l} \left[\frac{a^2}{2} - \frac{\gamma^2 a^6}{6(2 \cdot 4)^2} + \frac{\gamma^4 a^{10}}{10(2 \cdot 4 \cdot 6 \cdot 8)^2} - \dots \right]^2 \\ + \left[\frac{\gamma a^4}{4(2)^2} - \frac{\gamma^3 a^8}{8(2 \cdot 4 \cdot 6)^2} + \frac{\gamma^5 a^{12}}{12(2 \cdot 4 \cdot 6 \cdot 8 \cdot 10)^2} - \dots \right]^2 \end{array} \right.$$

FIG. 4.



Curve showing change of phase of current in cylindrical conductor with change of distance from axis.

At first glance this is an extremely difficult expression to handle, but I have found that it can be expressed in the remarkably simple form:

$$I_m^2 = \frac{(2\pi\lambda A)^2}{8} a^4 \left\{ 1 + \sum_{n=1}^{\infty} \gamma^{2n} a^{4n} \left(\frac{1}{n+1} \right) \left(\frac{1}{2n+1} \right) \left(\frac{1}{2 \cdot 4 \cdots 4n} \right) \left(\frac{1}{2 \cdot 4 \cdots 2n} \right)^2 \right.$$

We now have to consider the heating effect of the current in

the conductor. If u_m^2 is the mean square of the current density, the heating per unit length, W , is given by

$$W = \frac{1}{\lambda} \int_0^a 2\pi (u_m)^2 r dr$$

From equation (21), u_m^2 is equal to

$$u_m^2 = \left(\frac{\lambda A}{2}\right)^2 \left\{ \left[1 - \frac{(\gamma r^2)^2}{(2 \cdot 4)^2} + \frac{(\gamma r^2)^4}{(2 \cdot 4 \cdot 6 \cdot 8)^2} - \frac{(\gamma r^2)^6}{(2 \cdot 4 \cdots 12)^2} + \dots \right]^2 + \left[\frac{\gamma r^2}{2^2} - \frac{(\gamma r^2)^3}{(2 \cdot 4 \cdot 6)^2} + \frac{(\gamma r^2)^5}{(2 \cdot 4 \cdots 10)^2} - \dots \right]^2 \right\}$$

This series also admits of a simple formulation. Without going into the detailed work, W , the Joulean evolution of heat per second, may be written

$$W = \frac{\pi \lambda A^2}{2} a^2 \left\{ 1 + \sum_{n=1}^{\infty} (\gamma a^2)^{2n} \left(\frac{1}{2n+1} \right) \left(\frac{1}{2 \cdot 4 \cdots 4n} \right) \left(\frac{1}{2 \cdot 4 \cdots 2n} \right)^2 \right\}^2 \quad (23)$$

We have now obtained in equations (22) and (23) analytical formulæ for the mean square of the total current and the mean heat product per second. If we now define the resistance by the relation

$$I_m^2 R = W$$

we have

$$R = \frac{W}{I_m^2}$$

This quantity, R , which is the resistance per unit length, we shall denote by R_{ac} , since it holds for alternating currents. The resistance to steady direct current per unit length we shall denote by R_{dc} . Obviously,

$$R_{dc} = \frac{1}{\pi \lambda a^2}$$

As a result of the foregoing definition of R_{ac} , we have, by aid of equations (22) and (23),

$$R_{ac} = R_{dc} \frac{\left[1 + \sum_{n=1}^{\infty} (\gamma a^2)^{2n} \left(\frac{1}{2n+1} \right) \left(\frac{1}{2 \cdot 4 \cdots 4n} \right) \left(\frac{1}{2 \cdot 4 \cdots 2n} \right)^2 \right]}{\left[1 + \sum_{n=1}^{\infty} (\gamma a^2)^{2n} \left(\frac{1}{2n+1} \right) \left(\frac{1}{2 \cdot 4 \cdots 4n} \right) \left(\frac{1}{2 \cdot 4 \cdots 2n} \right)^2 \left(\frac{1}{n+1} \right) \right]} \quad (24)$$

Both numerator and denominator of the foregoing expression are highly convergent series in (γa^2) . It is interesting to note that the n^{th} term of the denominator is equal to the corresponding term of the numerator, multiplied by $\frac{1}{n+1}$. When $p = 0$, $\lambda = 0$, and the expression reduces to $R_{ac} = R_{dc}$, as we should expect.

The expression for R_{ac} can be thrown into the form

$$R_{ac} = R_{dc} [1 + c_1 (\gamma a^2)^2 + c_2 (\gamma a^2)^4 + c_3 (\gamma a^2)^6 + \dots]$$

and the coefficient— c_1 , c_2 , c_3 —calculated.

This gives

$$\frac{R_{ac}}{R_{dc}} = \left[1 + \frac{1}{12 \cdot 16} (\gamma a^2)^2 - \frac{1}{180 \cdot 16^2} (\gamma a^2)^4 + \dots \right]$$

This series is, however, very difficult to calculate for higher terms. I have therefore found it expedient, in calculating the values for the curves, Figs. 5 and 6, to compute the numerator and denominator of equation (24) separately for different values of λa^2 .

It is interesting to note that $\frac{R_{ac}}{R_{dc}}$, and all the effects due to current distribution are functions of $4\pi\lambda\mu \cdot pa^2$. This renders all curves universally applicable if the dimensions and electrical constants of the conductor and the frequency are given. p , of course, is equal to $2\pi\omega$ where ω is the number of cycles per second.

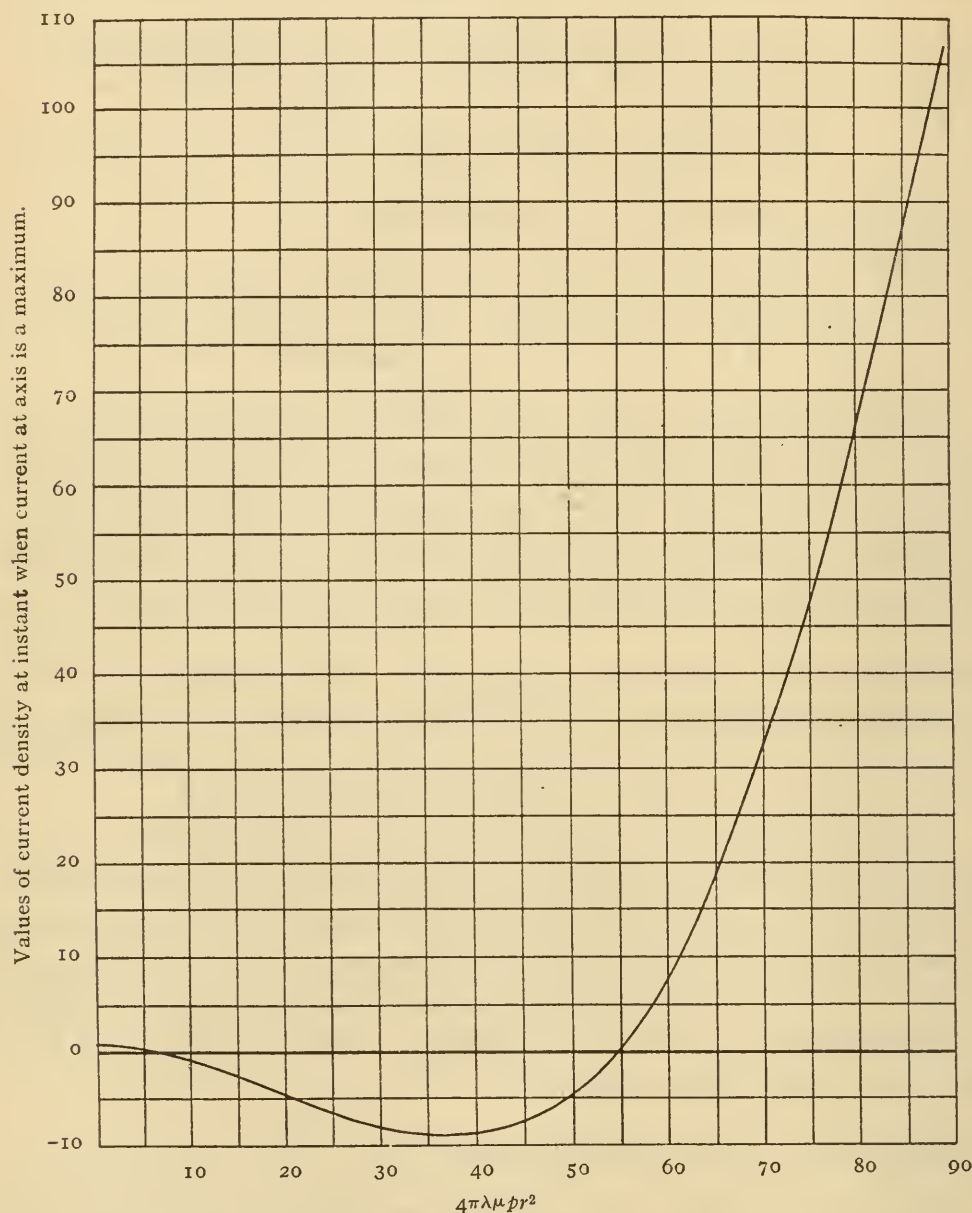
The mathematical expressions are so complicated, and so difficult of calculation as well as interpretation, that I have thought it advisable to express the results of the foregoing analysis in the form of curves. In this form of representation we can more readily arrive at a physical realization of the phenomena, while at the same time the quantitative results are more easily gotten from the curves than from tables.

Explanations of Curves and Tables.

The curves in Figs. 3 to 6, illustrative of the variations in phase and density of the current as we go out from the axis of the conductor, are plotted with values of $4\pi\lambda\mu \cdot pr^2$ as abscissæ. Curves in Figs. 7 and 8, which give the values of the ratio $\frac{R_{ac}}{R_{dc}}$, are plotted with values of $4\pi\lambda\mu \cdot pa^2$ as abscissæ, where a is the radius of the

conductor in centimetres. It must be carefully noted that λ , the conductivity, is expressed in absolute units; in substituting in this expression $4\pi\lambda\mu pa^2$, the conductivity in practical units must

FIG. 5.



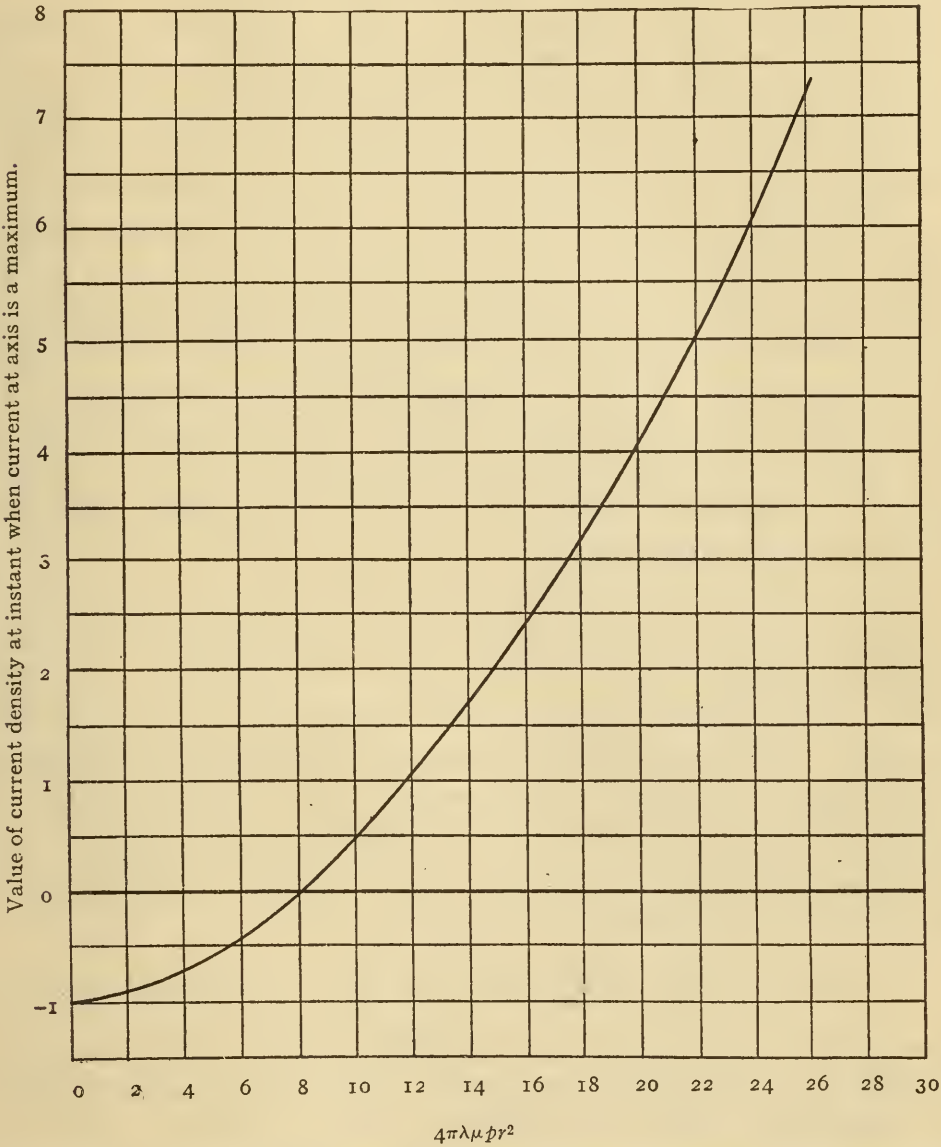
Curve of instantaneous current density in conductor of circular cross-section. $4\pi\lambda\mu pa^2 =$ one transverse wave-length.

be multiplied by 10^{-9} to convert it to the absolute system of units.

As an illustration of the use of these curves, we shall take a practical example for curves in Figs. 3 and 4. For copper, using the

value of $(5.88) 10^5$ as the conductivity in practical units, we have $4\pi\lambda\mu p = \infty (4.695) 10^{-2}$, where ∞ is the frequency in cycles per second. Taking the case of 60∞ we have $4\pi\lambda\mu p = 2.82$ approxi-

FIG. 6.



Curve of instantaneous current density in conductor of circular cross-section. $4\pi\lambda\mu pa^2 =$ one-half transverse wave-length.

mately. Now by reference to Fig. 4 we see that for a reversal of phase of current density $4\pi\lambda\mu pa^2 = 25.6$. Therefore in the case we have chosen, if $a^2 = \frac{25.5}{2.82}$, $a = 3$ cm., we have the condition

that the current at the axis is in exactly opposite phase from that at the surface. For higher frequencies this condition is attained for corresponding smaller values of conductor radius. Referring again to Fig. 4, we see that for $4\pi\lambda\mu o^2 = 90$, the current at axis and centre are in phase, the phase having changed through 360° in the interval $4\pi\lambda\mu r^2 = 0$ and $4\pi\lambda\mu r^2 = 90$. The radius corresponding to this interval is, in the case we have chosen, equal to 5.65 cm.; for 133 cycles it is 3.8 cm. This distance may very properly be called the first transverse wave-length, in contradistinction to the longitudinal wave-length along the axis of propagation.

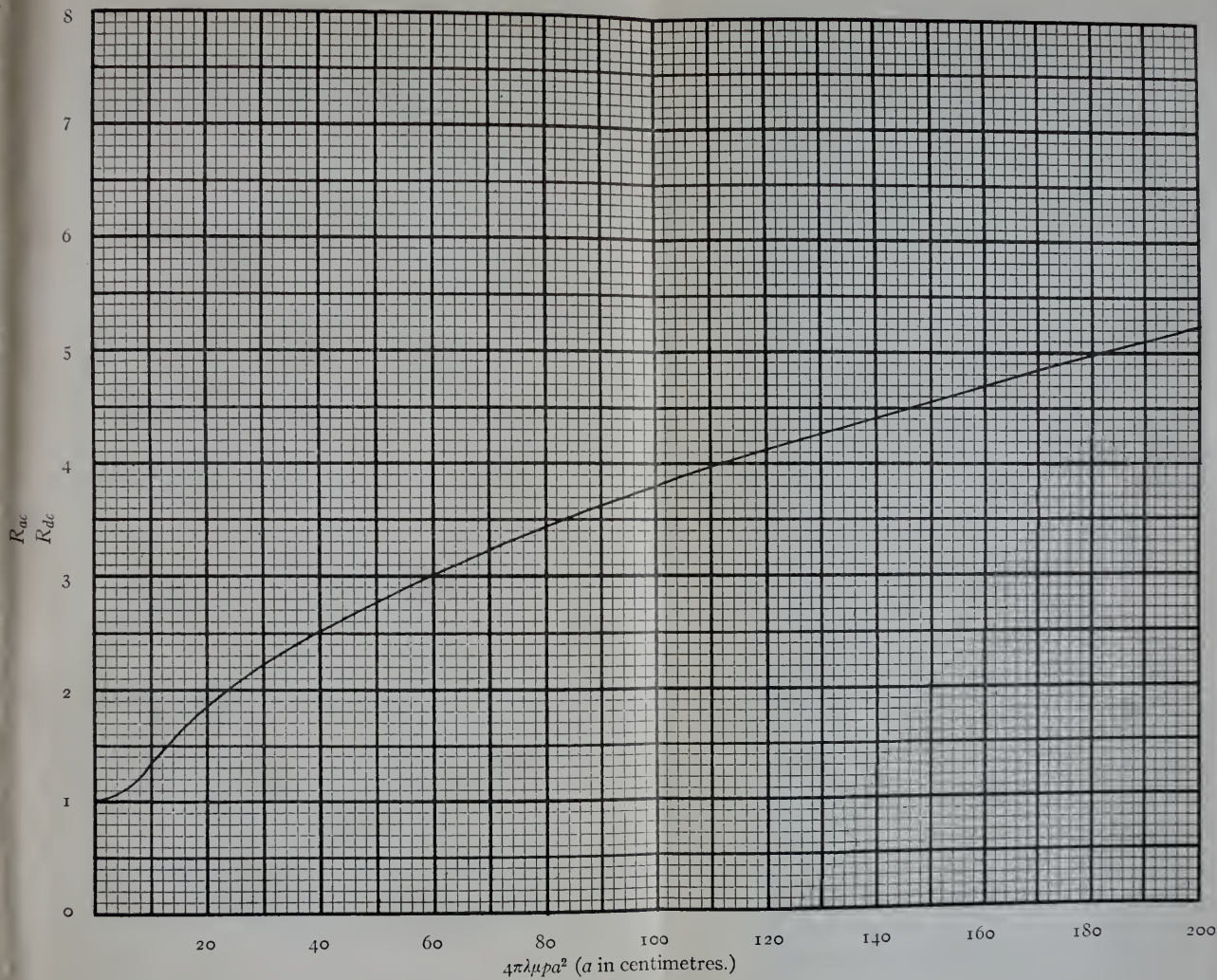
From Fig. 3 the corresponding current densities may be taken. If $4\pi\lambda\mu a^2 = 88$, the current density at the axis is only 1 per cent. of that at the circumference, and hence the inner part of the conductor is practically useless so far as its carrying capacity is concerned. In fact, we may go further and say that it is worse than useless, since the current the inner portion carries is in general opposed in phase, and therefore, while it increases the sum total of the Joulean heat developed, it actually diminishes the total current transmitted.

It is rather interesting to note from Figs. 3 and 4 that the change of phase is most rapid at the axis, while the change of current density is most rapid at the circumference. In other words, the transverse wave-lengths increase as we go out from the axis. The first complete transverse wave-length corresponds to the interval $4\pi\lambda\mu pr^2 = 0$ and $4\pi\lambda\mu pr^2 = 90$; the next half wave-length corresponds to the interval $4\pi\lambda\mu pr^2 = 90$ and $4\pi\lambda\mu pr^2 = 185$. In other words, the second half wave-length is slightly greater than the first complete wave-length.

To facilitate the computation of $\frac{R_{ac}}{R_{dc}}$ in practical cases, we have expressed equation (24) in different units, and in the easiest possible form for rapid computation. If ρ is the specific resistance per centimetre cube in microhms of the conductor, f the frequency in cycles per second, μ the permeability, and a the radius of the conductor in centimetres, equation (24) may be written

$$\frac{R_{ac}}{R_{dc}} = \frac{1 + c_1 \left(\frac{\mu f a^2}{\rho} \right)^2 + c_2 \left(\frac{\mu f a^2}{\rho} \right)^4 + c_3 \left(\frac{\mu f a^2}{\rho} \right)^6 + \dots}{1 + \frac{1}{2}c_1 \left(\frac{\mu f a^2}{\rho} \right)^2 + \frac{1}{3}c_2 \left(\frac{\mu f a^2}{\rho} \right)^4 + \frac{1}{4}c_3 \left(\frac{\mu f a^2}{\rho} \right)^6 + \dots} \quad (A)$$

FIG. 7.



Curve showing $\frac{R_{ac}}{R_{dc}}$ as function of $4\pi\lambda\mu pa^2$ for a solid conductor of circular cross-section.

The interesting relation between the coefficients of corresponding terms of numerator and denominator makes the computation of the denominator extremely easy, once the numerator is evaluated. Below is a table of the coefficients $c_1c_2 \dots c_6$ to six places :

$c_1 =$	$\dots\dots\dots (6 \cdot 49) \times 10^{-5}$
$c_2 =$	$\dots\dots\dots (3 \cdot 55) \times 10^{-10}$
$c_3 =$	$\dots\dots\dots (3 \cdot 24) \times 10^{-16}$
$c_4 =$	$\dots\dots\dots (1 \cdot 132) \times 10^{-22}$
$c_5 =$	$\dots\dots\dots (1 \cdot 55) \times 10^{-29}$
$c_6 =$	$\dots\dots\dots (1 \cdot 073) \times 10^{-36}$

The coefficients to six places will give the value of $\frac{R_{ac}}{R_{dc}}$ accurately for values of $\left(\frac{\mu fa^2}{\rho}\right)$ not exceeding $(1.3) \times 10^3$. The numbers of terms to which the expansion must be carried depends, of course, on the value of $\left(\frac{\mu fa^2}{\rho}\right)$ for the case chosen.

For values of $\left(\frac{\mu fa^2}{\rho}\right)$ between 1.25×10^3 and 2.5×10^3 the following approximate formula may be used with a high degree of accuracy :

$$\frac{R_{ac}}{R_{dc}} = 2.35 + (1.145) (10^{-3}) \left(\frac{\mu fa^2}{\rho}\right)$$

(B)

For values of $\left(\frac{\mu fa^2}{\rho}\right)$ lying between 2.5×10^3 and 3.8×10^3 , the approximate formula should be used :

$$\frac{R_{ac}}{R_{dc}} = 2.95 + (.908) (10^{-3}) \left(\frac{\mu fa^2}{\rho}\right)$$

(C)

As an example of the use of these formulæ, suppose we wish to determine $\frac{R_{ac}}{R_{dc}}$ for an iron conductor of permeability 1000, specific resistance of 10.4 microhms per centimetre cube, radius 1 centimetre, and frequency 25 cycles. Then we have

$$\frac{\mu fa^2}{\rho} = \frac{(1000) (25) (1)^2}{10.4} = (2.4) (10)^3.$$

We see from the value of $\frac{u fa^2}{\rho}$ that formula B may properly be applied, and by substitution therein we get

$$\frac{R_{ac}}{R_{dc}} = 1.25 + 2.75 = 4.0.$$

Again, if we have a copper conductor of radius 1 centimetre, specific resistance of 1.7 microhms per centimetre cube, at 60 cycles, $\frac{\mu fa^2}{\rho} = 35.3$. This value of $\frac{\mu fa^2}{\rho}$ is too small to permit of the use of either formula B or C, and we are therefore obliged to substitute in formula A.

Performing the indicated operations, we have

$$c_1 \left(\frac{\mu fa^2}{\rho} \right)^2 = .0808$$

$$c_2 \left(\frac{\mu fa^2}{\rho} \right)^4 = .00055$$

Subsequent terms become negligibly small, and we have

$$\begin{aligned} \frac{R_{ac}}{R_{dc}} &= \frac{1 + .0808 + .00055}{1 + \frac{1}{2}(.0808) + \frac{1}{3}(.00055)} \\ &= \frac{1.0813}{1.0407} = 1.04 \end{aligned}$$

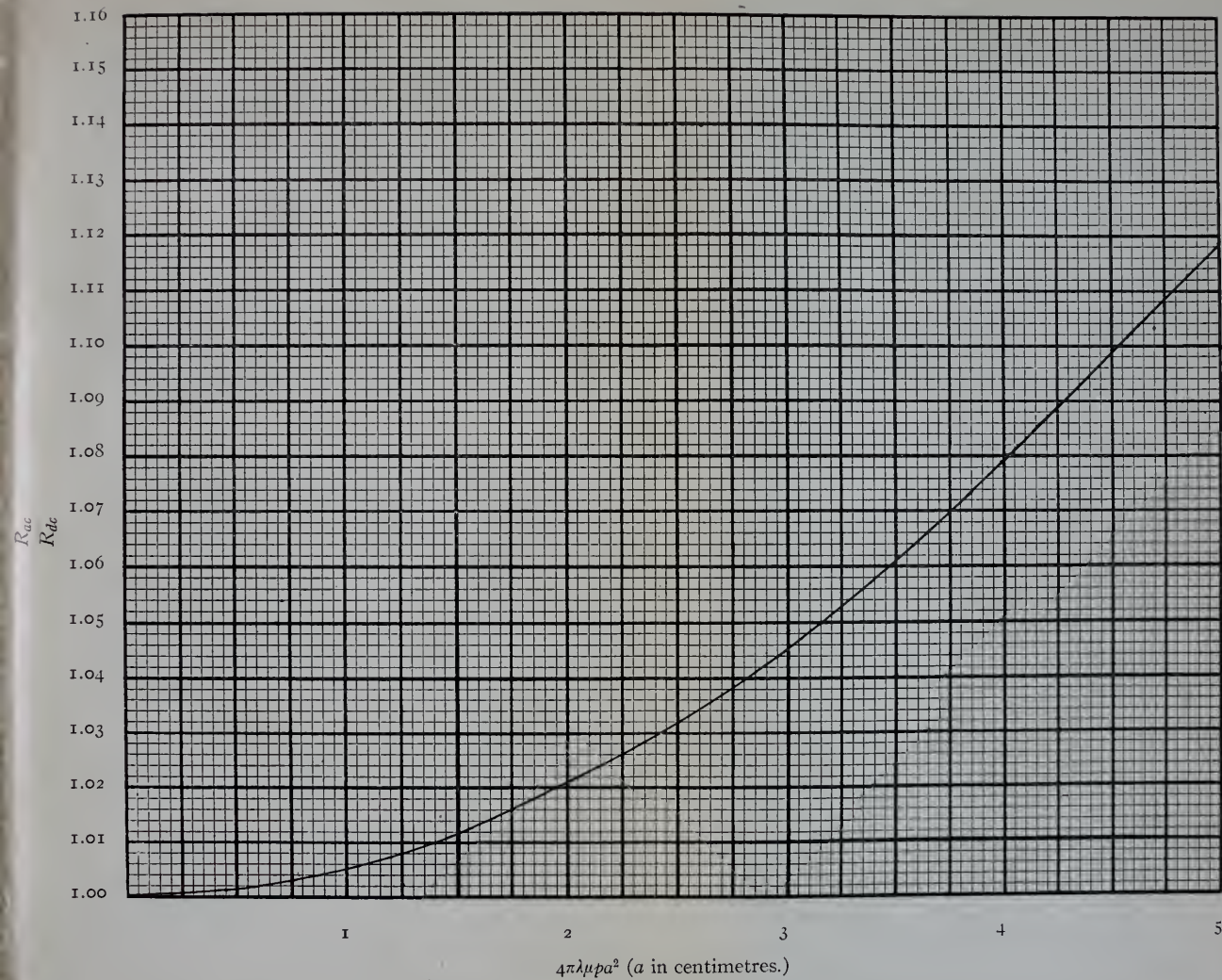
Hence in this case the resistance of the conductor to alternating current is 104 per cent. of its resistance to direct current.

If we choose a conductor of larger radius, operating at a higher frequency, higher terms in formula A become of importance, and the expansion must be carried out further.

In considering these theoretical results it behooves us to scrutinize the assumptions on which they rest, and to determine, in so far as we may, just when they may be safely applied in practice, and when, also, the assumptions depart so far from actual conditions as to vitiate our results. In the first place, we made the assumption that the cylindrical conductor was surrounded by a concentric cylindrical shell of conductive material, the two conductors being separated by the dielectric. This condition is not realized in practice, where we in general have two parallel conductors which are not concentric. Our analysis will not hold theoretically for this case. The complete solution for the case of parallel conductors has never been given, but it is known that higher orders of Bessel's Functions appear in this solution. However, if the radii of the conductors are small compared to the distance between their axes, the departure from the results predicted by the foregoing analysis would be very small, and the skin effect formulæ may be relied upon as very closely accurate.

A final word concerning a point which Dr. Northrup has

FIG. 8.



Curve showing $\frac{R_{ac}}{R_{dc}}$ as function of $4\pi\lambda\mu pa^2$ (a in centimetres.) for a solid conductor of circular cross-section.

brought out very fully; namely, the effect of the variation of permeability and the impossibility of analytically taking this effect into account. Going back to equation (6) in the first part of this section, we should write $\frac{d}{dt}(\mu H)$ instead of $\mu \frac{dH}{dt}$, if μ is variable. Since μ is a function of H , the magnetic force, we have

$$\frac{d}{dt}(\mu H) = \left(\mu + \frac{\delta \mu}{\delta H} \right) \frac{dH}{dt}$$

Here, however, analysis must stop. Not only is it impossible to express μ as a single function of H , but also μ is a double-valued function, which renders it impossible to integrate the resulting equation, supposing we could express μ as a function of H .

It follows, therefore, as Dr. Northrup has pointed out, that for ferrous conductors the theoretical formulæ do not accurately hold. They do, however, give the order of magnitude of the effect.

A final limitation to the generality of our formulæ must be noted. This is that the formulæ hold rigorously for long conductors only; in other words, for points in the conductor at a considerable distance from the disturbing effects of terminal conditions. The analytical introduction of this limitation is involved in our assumption that β , the attenuation constant, is very small. Theoretically there are an infinite number of values of β , and these may all be present at the terminal of the conductor. At considerable distances from the terminal, terms containing large values of β are damped out; finally at great distances from the terminal, only the term containing the smallest value of β is present.

The foregoing considerations are of greater theoretical than practical importance; the corrections which theory points out are probably too small to be detected experimentally in conductors longer than two metres.

V. EXPERIMENTAL INVESTIGATION OF THE ALTERNATING-CURRENT RESISTANCE OF IRON RODS.

(a) *The Method, Samples, and Apparatus.*

The object set in planning the experimental part of this research was to make a measurement of the alternating-current

resistance of three samples having different diameters, of round bars of iron of high permeability. As the alternating-current resistance was expected to depend both upon the frequency and the total current, the measurements were made using currents varying from 3 ampères to 43 ampères and for six frequencies. Perhaps the most precise and concise definition of the quantity we call alternating-current resistance is: a quantity numerically equal to the heat production, expressed in watts, per unit length of the conductor divided by the square of the total current flowing. Or we may say that the alternating-current resistance per unit length of a conductor is that quantity which, when multiplied by the mean square value of the total current, will give the power in watts which is being dissipated in unit length of the conductor. It is the quantity which should be employed when multiplying a resistance by the current to obtain in the triangle of electromotive forces, that component of the electromotive force which is in phase with the current.

In assigning a value to the alternating-current resistance obtained under given conditions it is convenient to express it as the ratio which it bears to the ordinary ohmic or direct-current resistance, the temperature being chosen the same in both cases.

The arrangements of the apparatus and method were planned to give a precision to within 1 per cent.

The three samples measured were round iron bars, each about 1.7 metres long. Samples No. 1 and No. 3 were not procured from the same place as No. 2, and were probably of a different kind of iron. This conclusion is made the more likely by determinations which were made of their resistivities. Reduced to microhms per centimetre cube at 25° C., the resistivities (within $\frac{1}{4}$ of 1 per cent.) were:

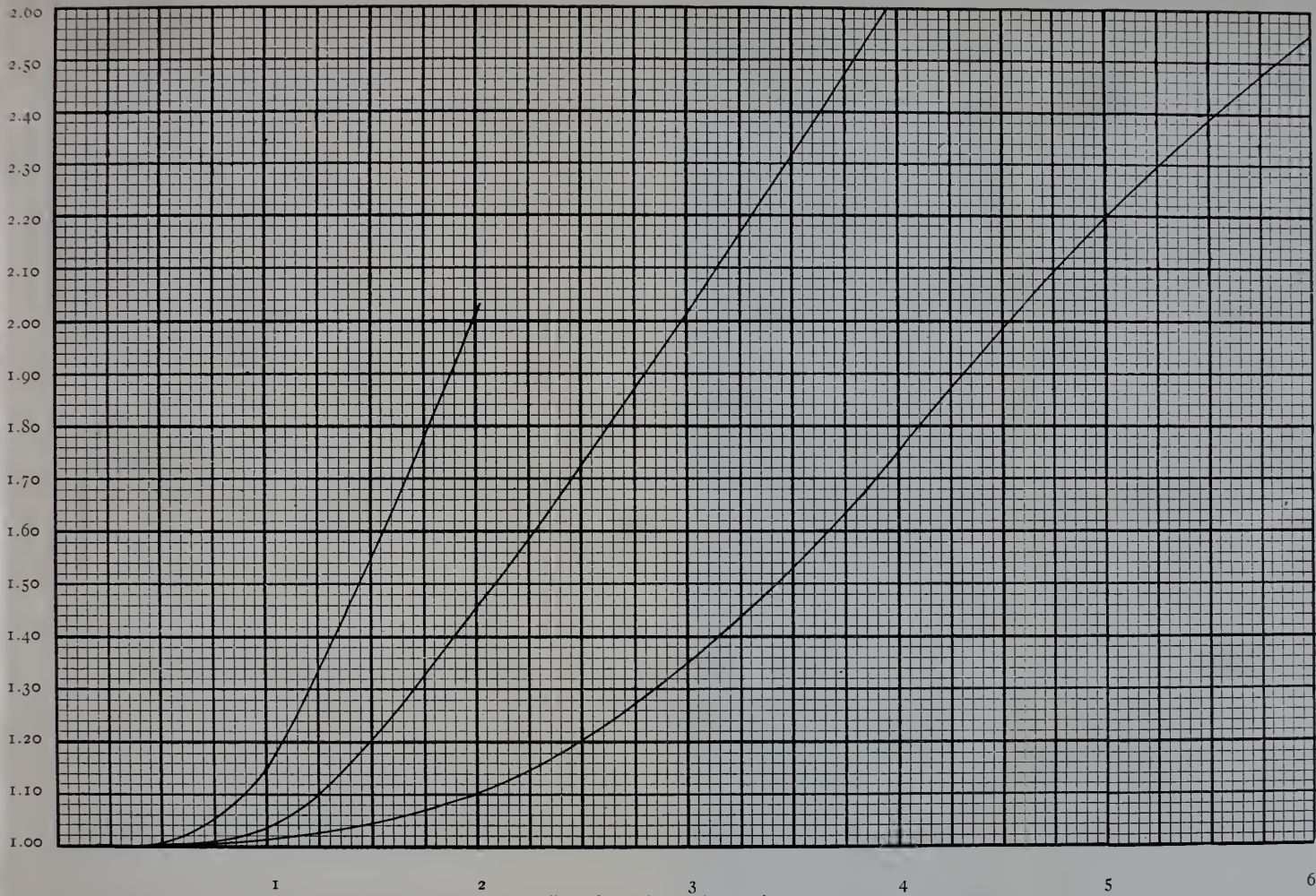
Sample No. 1—12.35 microhms.

Sample No. 2—14.63 microhms.

Sample No. 3—12.77 microhms.

Unfortunately, time was not available to determine their permeability curves. The iron was purchased for a good quality wrought iron. The general course of the curves and the characteristics which they exhibit would be affected in magnitude rather than in kind by iron having a different permeability, and it is thought that the above omission does not much lessen the value of

FIG. 9.

133 \sim 60 \sim 25 \sim 

Radius of conductor in centimetres.

Curve showing $\frac{R_{ac}}{R_{dc}}$ for a copper conductor of circular cross-section. 133, 60, and 25 cycles.

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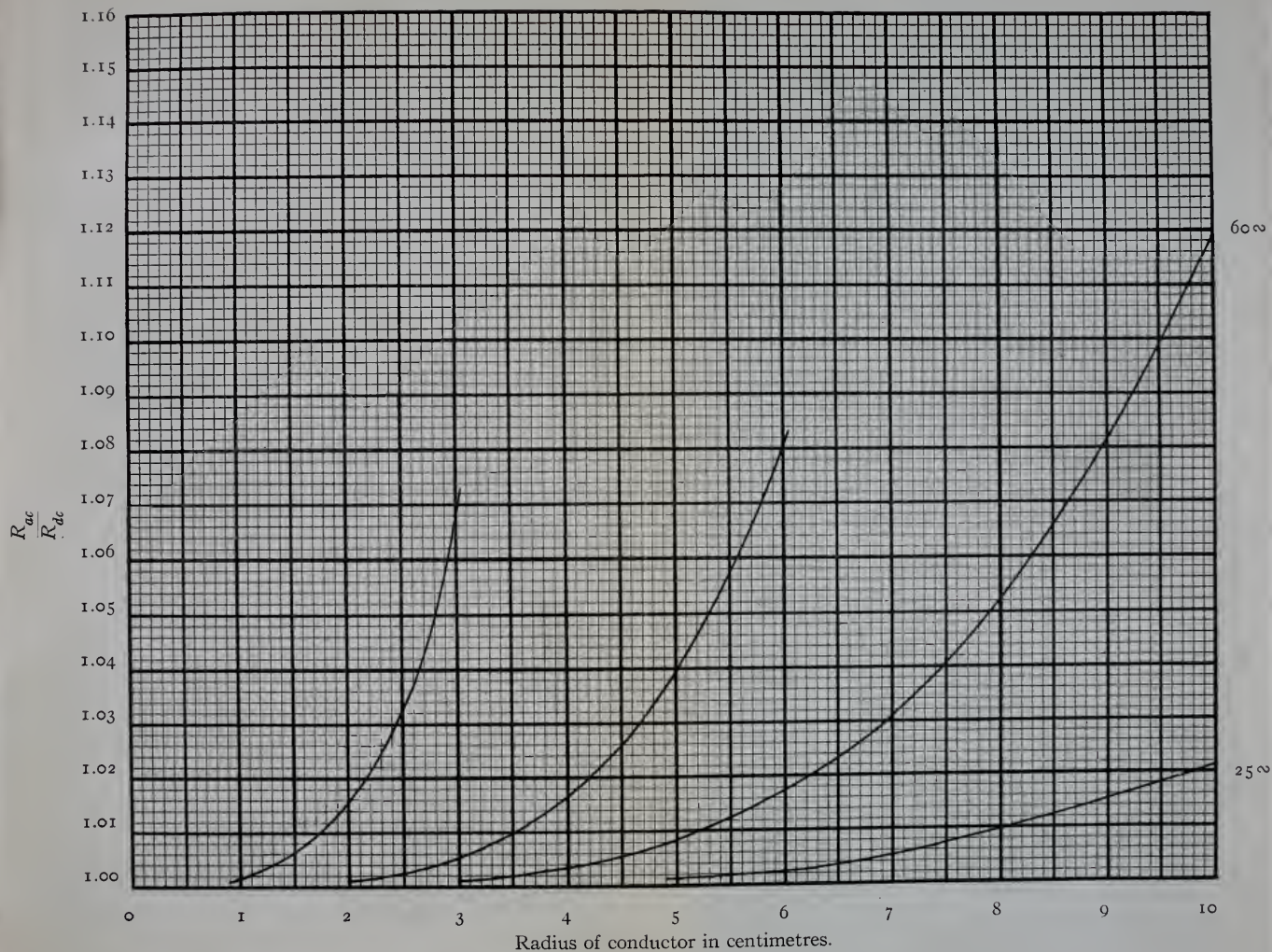
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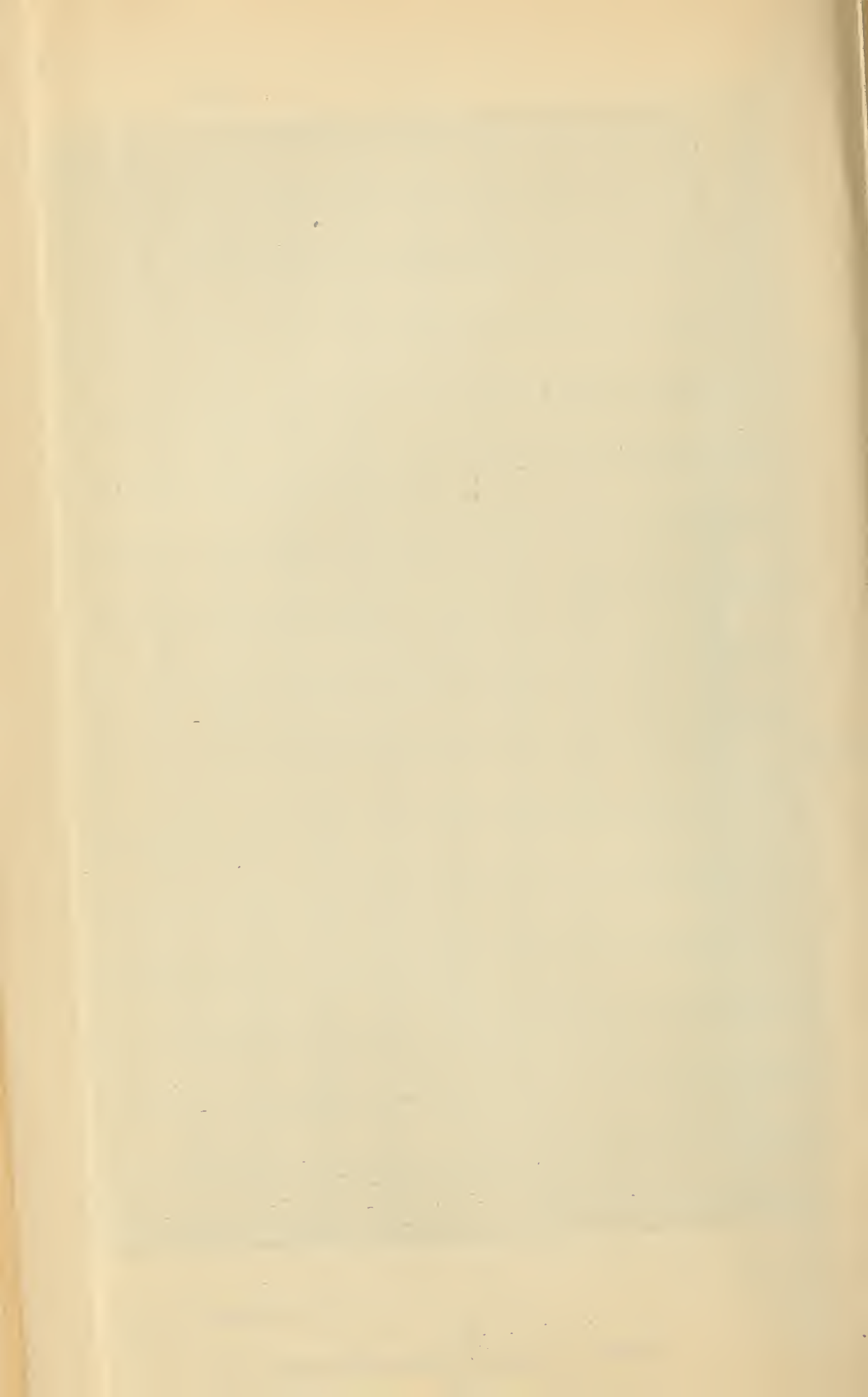
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FIG. 10.

500 \sim 133 \sim 

Curve showing $\frac{R_{ac}}{R_{dc}}$ for a mercury conductor of circular cross-section. 500, 133, 60, and 25 cycles.



the experimental results and not at all the general conclusions to be drawn. The diameters of the rods were:

Sample No. 1 = 0.953 cm. ($\frac{3}{8}$ ").

Sample No. 2 = 1.905 cm. ($\frac{3}{4}$ ").

Sample No. 3 = 3.493 cm. ($1\frac{3}{8}$ ").

At four or five points along each rod small holes were drilled and copper wires driven in to serve as potential points. Thus various lengths of rod could be selected for measurement, the choice of length being made to give the best obtainable sensibility and yet be within the range of the resistance of the mercury standard used in the comparison.

The full description and theory of the general method employed has already been given by Edwin F. Northrup in the *Proceedings of the A. I. E. E.*, June, 1912, and in his book "Methods of Measuring Electrical Resistance," Chapter X. Some minor modifications were employed and a specially-constructed mercury standard was used. This consisted of a tube of hard gray fibre mounted vertically and filled with mercury. The length of the mercury column could be varied. The sliding terminal was so arranged with a fixed scale that the length of the mercury column in circuit could be read to fractions of a millimetre. In reality, however, the resistance used as the standard also included a certain amount of copper. The diagram Fig. 11 shows the arrangement employed.

The more important dimensions of this variable standard are:

Diameter of sliding copper rod = 0.955 cm.

Length of sliding copper rod = 128.4 cm.

Length of fixed copper rod in bottom of mercury column = 16.4 cm.

Diameter = 0.955 cm.

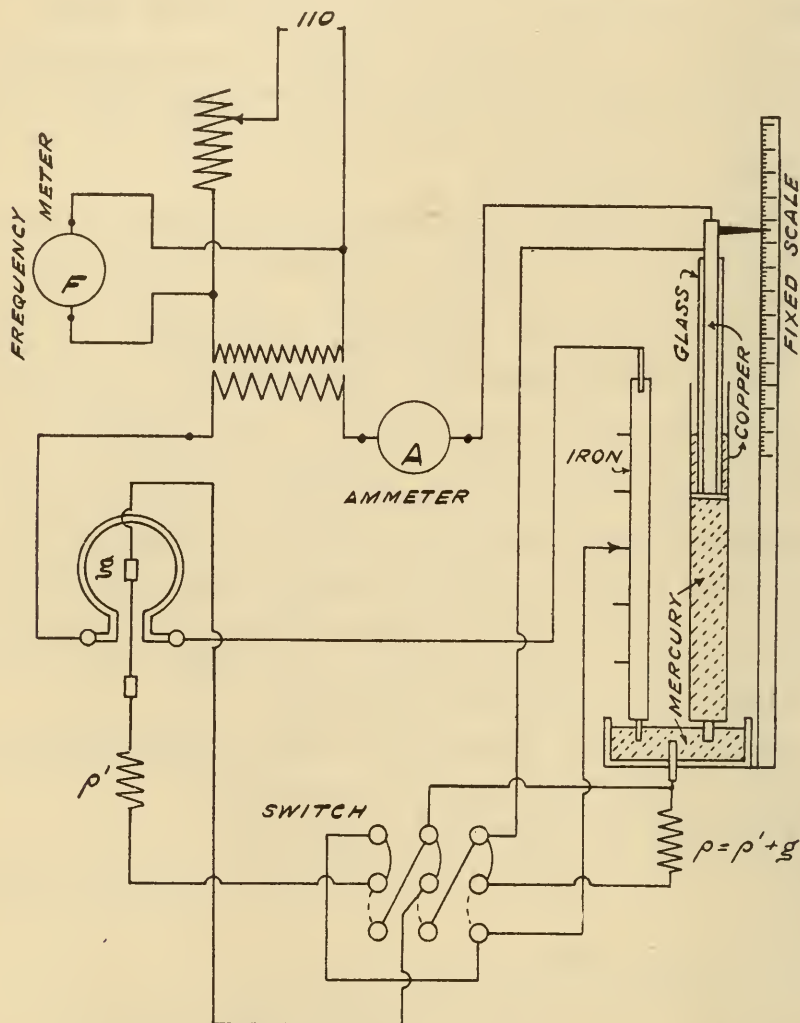
Inside diameter of fibre tube = 2.00 cm.

The length of the mercury column, which entered the circuit, could be varied from 0 to 58.5 cm. One end of the iron sample terminated in a short, thick copper plug. This plug was immersed to its full length in one end of a trough of mercury of considerable cross-section, and the lower copper terminal of the mercury column was immersed in the other end of the trough. The distance between the end of the standard and the end of the sample varied from 1.5 to 3 centimetres. One potential point was taken

off at the point where the copper plug inserted in the end of the iron rod entered the mercury trough.

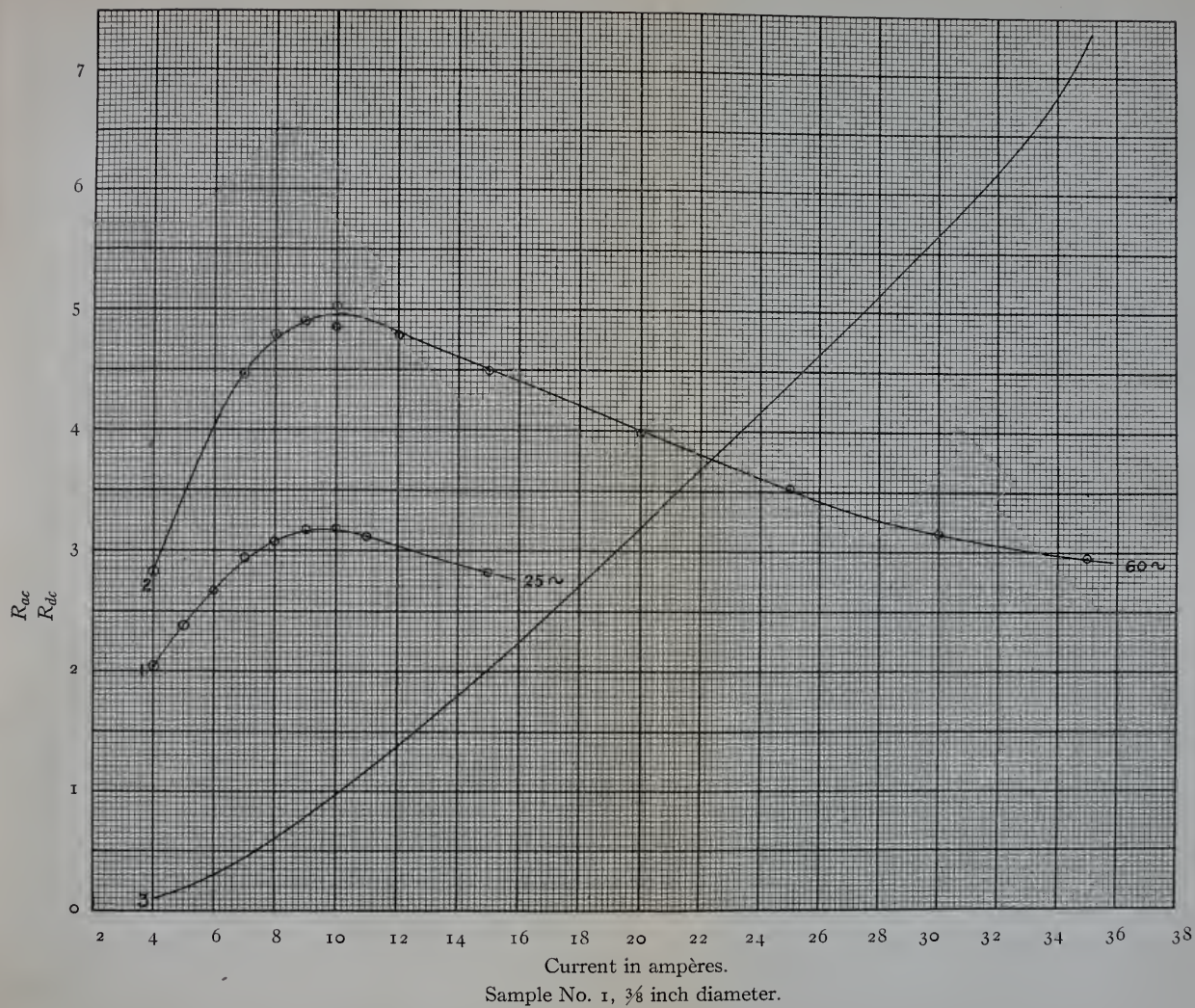
It was assumed, and subsequent analysis proved, that for the frequencies used and the precision sought the skin effect of the standard was entirely negligible,—that is, its alternating-current resistance is sensibly the same as its direct-current resistance. The

FIG. II.



resistance of the standard for various scale positions was accurately measured with a Kelvin double bridge either immediately before or after making a set of alternating-current resistance measurements, and a curve (in fact, a straight line) was drawn. Then when a balance was obtained, using alternating current, it was only necessary to refer to the curve to obtain the resistance for the setting of the standard which gave the balance and hence the alternating-current resistance for the particular current and frequency used.

FIG. 12.



The alternating current was supplied from the low-tension side of a transformer with a ratio of 20 to 1. The high-tension side of the transformer was joined to a rotary converter, and this was fed from a storage battery of 120 volts. In this way reasonably steady current and frequency were obtained. To regulate frequency and current, suitable rheostats were placed in the field circuit of the rotary converter and in the high-tension circuit of the transformer.

To measure frequencies between 35 and 65 cycles, a Westinghouse frequency meter was used; and for frequencies outside this range the revolutions per minute were taken, from which the frequency was readily calculated.

The currents were measured with a Westinghouse 5- and 10-ampère scale ammeter in conjunction with a suitable current transformer.

The electro-dynamometer used was a Rowland-deflection type instrument, with an astatic moving system. Its heavy coil would carry from 45 to 50 ampères. It is made and listed by the Leeds and Northrup Company, Catalogue No. 7425. While this instrument served our purpose, its capacity would be too small for a study of the alternating-current resistance of conductors of large cross-section, such as steel rails. An instrument specially fitted to the work of this character could easily be constructed.

Two or more thermometers were fastened against the surface of the sample being measured by which account was taken of the temperature.

The apparatus as used was connected as shown in the diagram of connections Fig. 11.

As actually set up, all the leads carrying large currents were arranged, as far as possible, non-inductively to eliminate any inductive electromotive forces in the dynamometer potential lead circuits which might lead to erroneous results. With this arrangement a reading was obtained on the dynamometer which was made the same, by varying the mercury standard, whether the swinging coil of the dynamometer was joined across the standard or across the sample. The leads of the swinging coil were then shifted into many positions to determine if there were any induced electromotive forces in this part of the circuits which would affect the reading. None were found.

It was recognized that the non-inductive arrangement of

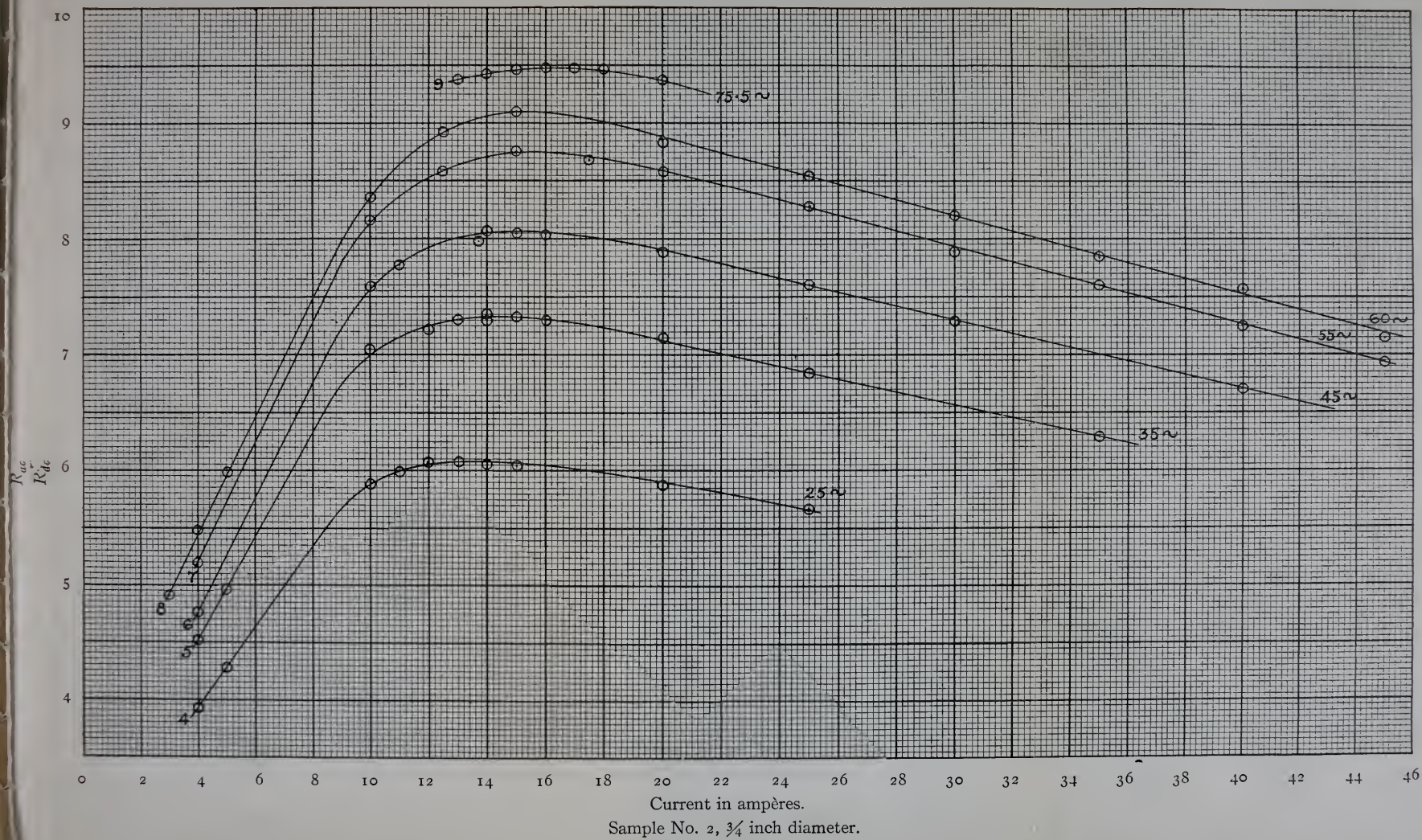
standard and sample employed might lead to an error in the measurement of the resistance for any given current, for the current in the standard, being but about 3 centimetres from the iron rod, would cause inductive effects in the iron. As arranged the two were in a vertical position, and it was possible to incline the iron rod to make any angle with the standard. A balance was obtained using the $1\frac{3}{8}$ -inch bar and 35 ampères and 60 cycles, when both were vertical. The iron rod was then inclined to make an angle of 60° with the standard. An increase in the resistance of a trifle less than 1 per cent. was observed. For lower values of frequency, current, and diameter this error would, we judge, be less. It thus appears that lines of force external to the conductor have but small effect upon the alternating-current resistance, and we think the non-inductive disposition of sample and standard is to be preferred to an inductive disposition because of the reduced chance with the former arrangement of inductive action upon the potential leads. If such were present, considerable error might be caused.

The error which would have resulted from the heating of the rod by the rather large currents used was estimated by taking the temperature of the rod at the time of each reading and making a correction by assuming 0.6 per cent. increase in resistance for each degree Centigrade. The standard did not heat appreciably and also had a lower temperature coefficient, and its resistance was assumed constant.

Using sample No. 2, readings were taken for various currents at frequencies of 75.5, 60, 55, 45, 35, and 25 cycles per second. The frequency of 75.5 cycles was the highest obtainable as the apparatus was arranged. Using samples No. 3 and No. 1, but two frequencies were used, viz., 60 and 25 cycles, these being the more important commercial frequencies. For low currents the results were less accurate on account of the lessened sensibility of the dynamometer with small current. The limitations for high currents were due to the heating of the large coil of the dynamometer and to the voltage available.

Although the direct-current resistance of the samples could have been measured with the dynamometer and circuits as set up, we preferred to measure this resistance in each case by means of a Kelvin double bridge. In the alternating-current resistance determinations the length of iron used was varied, as above stated, but in obtaining the ratio of alternating-current resistance to

FIG. 13.



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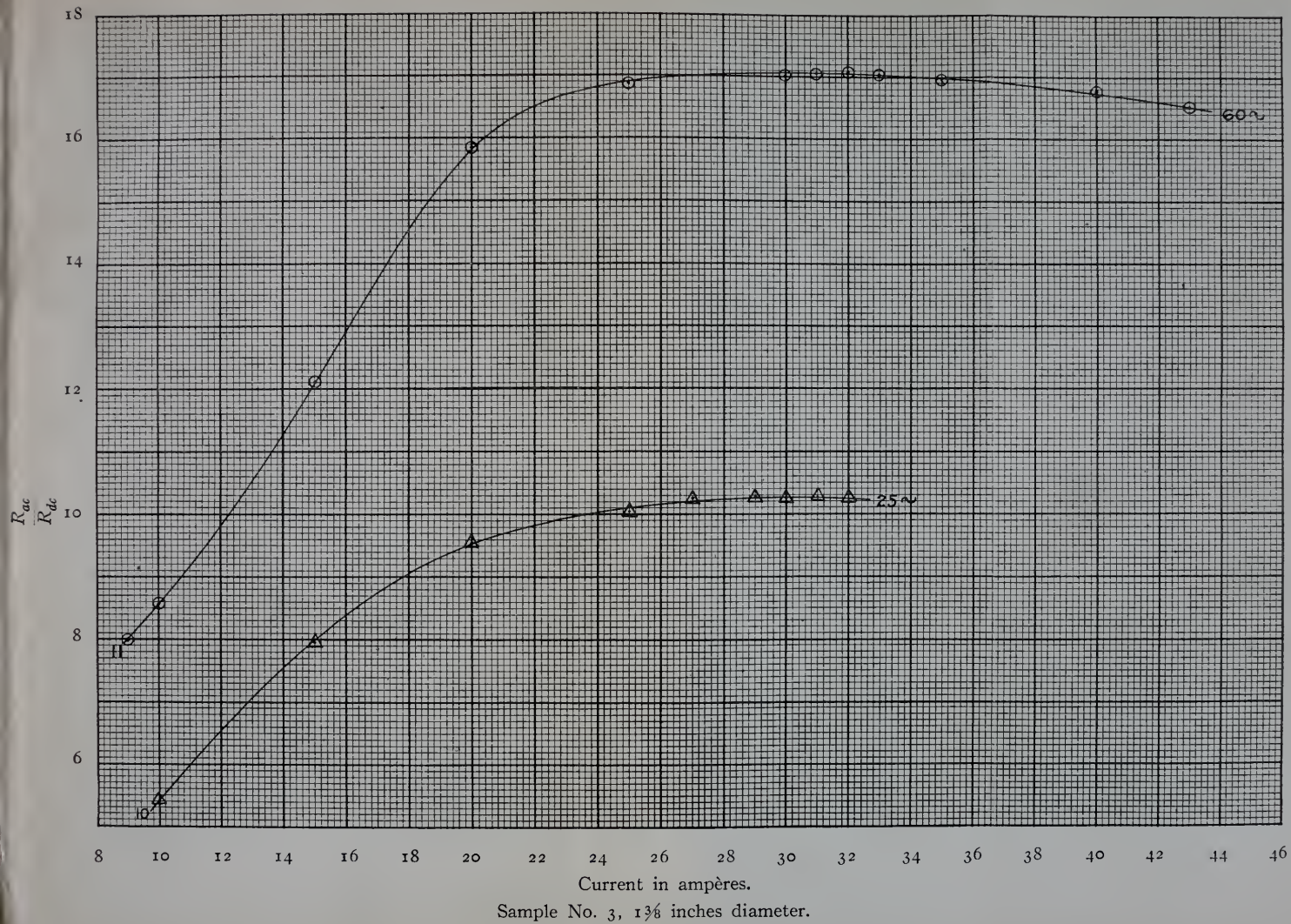
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FIG. 14.



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direct-current resistance all resistances were reduced to rods of the same length.

(b) *The Experimental Results.*

All the experimental data obtained by our measurements are embodied in curves 1 and 2, Fig. 12, curves 4, 5, 6, 7, 8, and 9, Fig. 13, and curves 10 and 11, Fig. 14.

Curve 3, Fig. 12, and curves 12, 13 and 14, Fig. 15, exhibit no new data, but present the same facts in different forms.

All the curves of experimental data show one striking feature; namely, the ratio of the alternating-current resistance to the direct-current resistance at first increases quite rapidly, and then more slowly decreases as the total current through the conductor is increased. Curve No. 2, Fig. 12, would seem to indicate that the ratio is approaching about 2.5 as an asymptotic value. The current value for which the ratio of the alternating-current to direct-current resistance reaches a maximum shifts by a small amount with change in frequency. In the case of sample No. 1 the ratio is a maximum at 25 cycles when the current is 9.4 ampères and at 60 cycles when the current is 9.8 ampères. The corresponding figures for sample No. 2 are 13 ampères and 15.5 ampères.

A surprising result of the measurements is the very large values obtained for the ratio of the alternating-current to the direct-current resistance. With the commercial frequency of 60 cycles the maximum value of the ratio for a rod of soft iron $\frac{3}{8}$ -inch diameter is 4.93; for a similar rod of $\frac{3}{4}$ -inch diameter it is 9.11, and for a similar rod of $1\frac{3}{8}$ -inch diameter it attains the very large value 17.1. The diameters of these rods are in the ratios

1 : 2 : 3.66. The $\frac{R_{ac}}{R_{dc}}$ values are in the ratios 1 : 1.85 : 3.46.

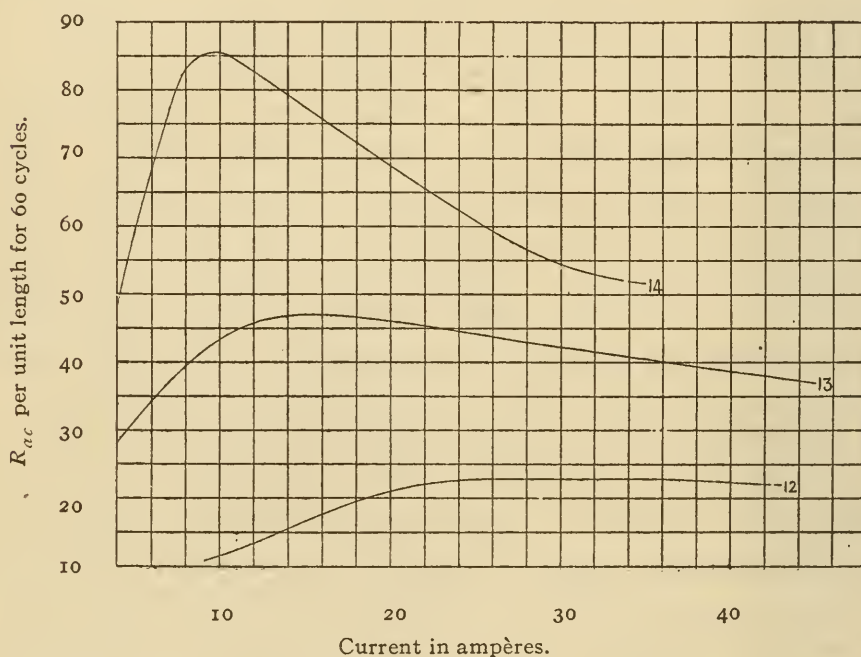
Hence the increase in the ratio of the maximum alternating-current resistance to the direct-current resistance is roughly proportional to the diameter of the rod.

Although the alternating-current resistance reaches a maximum and then declines rather rapidly, this decline is not sufficient but that the curve which has ordinates proportional to the watts lost, and abscissæ equal to the total current, rapidly rises. This is shown by curve 3, Fig. 12.

In Fig. 15 three curves give the actual alternating-current resistance in microhms per unit length of samples Nos. 1, 2, and 3 when the frequency is 60 cycles, and the current increases from its

least to its greatest value. We note from these curves that, if the iron conductors are made to carry 35 ampères each, at 60 cycles, the watts consumed per centimetre length are: for sample No. 1, $51.5 \times 10^{-6} \times 35^{-2} = 0.063$; for sample No. 2, $40.05 \times 10^{-6} \times 35^{-2} = 0.049$; and for sample No. 3, $22.5 \times 10^{-6} \times 35^{-2} = 0.0276$. The ratio of the last to the first is $\frac{22.5}{51.5} = 0.436$. But the ratio of the cross-section of sample No. 3 to the cross-section of sample No. 1 is 13.44. Thus, if it is required that a

FIG. 15.



conductor transmit 35 ampères at 60 cycles, to reduce the power loss to 0.436, or by a little more than half, we must increase the cross-section,—that is, the weight and cost of the iron,—13.44 times. Considerations of this character reveal the importance in engineering practice of experimentally tracing the curves of alternating-current resistance of conductors of ferrous material which are designed to carry large alternating currents or transmit alternating-current power.

It is interesting to further note that the maximum value of the alternating-current resistance at 60 cycles per unit length for samples Nos. 3, 2, and 1 are 23, 47, and 85.5 microhms respectively. These numbers are in the ratios 1 : 2.04 : 3.71, while the diameters of the samples Nos. 1, 2, and 3 are 0.9525 cm., 1.90 cm., and 3.492 cm. respectively, or are in the ratios 1 : 2 : 3.66. It

appears from this last that the maximum value of the alternating-current resistance (for 60 cycles at least) is very nearly inversely proportional to the diameter of the rod. Or, stated in another way, the product of the maximum alternating-current resistance and the diameter of the rod is constant. If we express the resistance per centimetre length in ohms and the diameter in centimetres, these products become for samples Nos. 1, 2, and 3, 81.4×10^{-6} , 89.3×10^{-6} and 80.3×10^{-6} respectively. The fact that this product in the case of sample No. 2 is larger than in the other two cases may well be accounted for by observing that its direct-current resistivity is 14.63 microhms, as against 12.35 and 12.77 microhms for samples Nos. 1 and 2.

In the case of conductors of circular cross-section and of non-magnetic material the one general relation which holds exactly is this: the ratio of the alternating-current resistance to the direct-current resistance depends only upon the product of the conductivity of the material, the frequency, and the square of the diameter of the conductor. So long as the product of these three factors remains constant $\frac{R_{ac}}{R_{dc}}$ is unchanged.

VI. THE ENGINEERING FEATURES OF THE EXPERIMENTAL RESULTS.

There are at least three important cases in engineering practice where the skin effect may play a prominent part: in third-rail transmission, in power transmission by means of copper-clad iron conductors, and in the short and very heavy copper conductors which carry large alternating currents from the low-tension side of transformers to electric furnaces. In the last case only, would it be possible to predict without experiment the approximate magnitude of the effect. Furthermore, if conductors of non-magnetic material have a cross-section other than circular, the mathematical calculation of the skin effect would be practically impossible. In all these cases it is very desirable to accumulate experimental data. It is not thought that it would be necessary to measure the ratio, $\frac{R_{ac}}{R_{dc}}$, for every size and shape of iron conductor. It is probable that by measuring a few samples of widely different cross-sections but of similar contour and at different frequencies and with different current values, etc., empirical relations would be observed which would permit quite accurate interpolations to be made for other cross-sections, frequencies, currents, permeabilities, etc.

The study of ohmic resistances through moderate ranges of temperature has been pursued quite extensively, but very little has been done in the determination of alternating-current resistances, and it is predicted that this matter will receive the attention it deserves in the near future.

As the skin effect only manifests itself to any appreciable extent in conductors designed to carry power, and as it always acts to increase the loss of power in the conductor, it is an unmitigated evil, and the question naturally arises, how can the skin effect be reduced? In answering this question attention should first be directed to the fact that the skin effect is almost wholly a phenomenon of the lines of induction on the interior of the conductor. It is, therefore, impossible to diminish it by subdividing the conductor into strands which lie close together or by giving to the return conductor any non-inductive disposition. It may, however, be diminished by disposing the material in the form of a tube or a sheet. It can be greatly diminished by decreasing the permeability. Thus steel rails of a certain composition are made which are practically non-magnetic. Even though these show a higher ohmic resistance than ordinary steel rails, they might prove to be very much better carriers of alternating current. If it is possible to divide a conductor into many strands and then intermingle the strands of the return conductor with the strands of the outgoing conductor, the skin effect would be greatly diminished. This procedure might be applied in connection with electric furnaces.

Another question is: Does the ratio of the alternating-current resistance to the direct-current resistance in ferrous materials increase only with the skin effect? It is believed by the writer that this is practically the main cause of the increase, but that the hysteresis of the iron must play a small part in increasing the ratio. The true magnitude of this effect can, however, only be determined by measurement.

The writer believes that in the present paper we have only scratched the surface of this very complex and extensive subject, and he suggests that the experimental investigation of the skin effect and alternating-current resistance would prove an instructive and fruitful line of endeavor for many engineering students who are in search of subjects for theses.

PROPORTIONING OF LONG-SPAN TRUSS AND CANTILEVER BRIDGES.*

BY

JOSEPH MAYER,

Assistant Engineer, Quebec Bridge Commission, Montreal, Canada.

The load W_μ produces at the distance z from the end of the cantilever arm a moment

$$\begin{aligned} M_z &= \int_{x=0}^{x=z} \mu (z-x) (AM_x + BS_x) dx \\ &= \mu \int_{x=0}^{x=z} (z-x) \left[A \frac{x(l_s+x)}{2} + B \left(x + \frac{l_s}{2} \right) \right] dx \\ &= \mu \left[A \left(\frac{Z^4}{24} + \frac{Z^3 l_s}{12} \right) + B \left(\frac{Z^3}{6} + \frac{Z^2 l_s}{4} \right) \right] \end{aligned}$$

Changing Z to x and using a more accurately descriptive index for M_x , we obtain

$$M_x^{d_{1c}} = \frac{\mu x^2}{24} \left\{ Ax (x + 2l_s) + 2B (2x + 3l_s) \right\}$$

The symbol $M_x^{d_{1c}}$ indicates the moment at the distance x from the end of the cantilever arm produced by the weight of the cantilever truss required to carry the moving load μ per foot of bridge. The effect of the weight of the suspended span is not included.

The load W_μ produces at the distance x from the end of the cantilever arm a shear

$$S_x^{d_{1c}} = \int_0^x \mu \left\{ \frac{Ax (l_s + x)}{2} + B \left(x + \frac{l_s}{2} \right) \right\} dx$$

$$\text{or} \quad S_x^{d_{1c}} = \frac{\mu x}{12} \left\{ Ax (2x + 3l_s) + 6B (x + l_s) \right\}$$

*Concluded from page 64.

The moving load μ_s per foot of suspended span gives a dead load $\mu_s C_m l_s^2$ and at the end of the cantilever arm a load

$$\mu_s \frac{C_m l_s^2}{2}$$

This load gives at the distance x from the end of the cantilever arm a moment

$$M_x^{d_{1s}} = \frac{\mu_s C_m l_s^2 x}{2}$$

Adding this to the moment $M_x^{d_{1c}}$, we obtain

$$M_x^{d_1} = \frac{\mu x^2}{24} \left\{ Ax(x + 2l_s) + 2B(2x + 3l_s) + \frac{12\mu_s C l_s^2}{x \cdot \mu} \right\}$$

This is the moment produced at the distance x from the end of the cantilever arm by the weights of the suspended span truss and the cantilever truss required for the moving load and impact stresses.

For the corresponding shear we obtain

$$S_x^{d_1} = \frac{\mu x}{12} \left\{ Ax(2x + 3l_s) + 6B(x + l_s) + \frac{6\mu_s}{x\mu} C_m l_s^2 \right\}$$

The weight of steel in the trusses in the length dx at the distance x from the end of the cantilever arm to carry the first dead loads due to the trusses for the moving load stresses from the loads μ_s and μ_d is

$$dW_\mu^{d_1} = V (AM_x^{d_1} + BS_x^{d_1}) dx$$

The equivalent uniform slowly moving load $\mu = m_r (1 + I) + m_h$ for the chords is for long spans but little larger than the load per foot behind the engines plus the highway load per foot.

The floor-beam hangers and other members carrying but one panel load or less have a larger impact and larger excess from the engines than the chords. These are allowed for in the coefficient of B . In the trusses required for the dead loads these excesses do not occur. The weight of the trusses to carry a given dead load is, therefore, smaller than that required to carry an equal slowly

moving load μ . To allow for this fact the coefficient V is introduced; it is smaller than 1.

Introducing in the last equation the above values for M_x^d and $S_x^{d_1}$ we obtain

$$dW_\mu^{d_1} = V \left[\frac{\mu A x^2}{24} \left\{ A x (x + 2l_s) + 2B (2x + 3l_s) + \frac{12\mu_s}{x \cdot \mu} C_m l_s^2 \right\} \right. \\ \left. + \frac{\mu B x}{12} \left\{ A x (2x + 3l_s) + 6B (x + l_s) + \frac{6\mu_s}{x\mu} C_m l_s^2 \right\} \right] dx$$

or

$$dW_\mu^{d_1} = \frac{\mu V}{24} dx \left[A^2 x^3 (x + 2l_s) + 4ABx^2 (2x + 3l_s) \right. \\ \left. + 12B^2 x (x + l_s) + \frac{12\mu_s}{\mu} C_m l_s^2 (Ax + B) \right] \\ W_\mu^{d_1} = \int_0^{lc} dW_\mu^{d_1} = \frac{\mu V l_c}{240} \left\{ A^2 l_c^3 (2l_c + 5l_s) + 20AB l_c^2 (l_c + 2l_s) \right. \\ \left. + 20B^2 l_c (2l_c + 3l_s) + 60 \frac{\mu_s}{\mu} C_m l_s^2 (Al_c + 2B) \right\}$$

This is the weight of steel required in the cantilever arm to carry W_μ and the suspended span trusses for the moving load and impact stresses.

If for $\mu_s C_m l_s^2$, which is the weight of steel in the trusses of the suspended span required for the moving load and impact stresses, we place the whole weight W_s of the suspended span, replacing $\mu_s C_m l_s^2$ by W_s , then we obtain

$$dW_\mu^{d_1} = \frac{\mu V dx}{24} \left\{ A^2 x^3 (x + 2l_s) + 4ABx^2 (2x + 3l_s) \right. \\ \left. + 12B^2 x (x + l_s) + \frac{12W_s}{\mu} (Ax + B) \right\}$$

and for $W_\mu^{d_1}$ we obtain

$$W_\mu^{d_1} = \frac{\mu V l_c}{240} \left[Al_c^2 \left\{ Al_c (2l_c + 5l_s) + 20B (l_c + 2l_s) \right\} + \right. \\ \left. 20B^2 l_c (2l_c + 3l_s) + \frac{60W_s}{\mu} (Al_c + 2B) \right] \dots \dots \dots (50)$$

This is the weight of steel required in the cantilever trusses to carry W_μ and W_s .

From $dW_\mu^{d_1}$ we obtain $dW_\mu^{d_2}$ and $W_\mu^{d_2}$ in a similar manner as $dW_\mu^{d_1}$ and $W_\mu^{d_1}$ were obtained from dW_μ and W_s .

And by the same process $W_\mu^{d_2}$ and $W_\mu^{d_3}$ were obtained by repeated integration. They are given in the foregoing text.

LATERALS AND CROSS BRACING.

The formulas for the weights of the laterals and the cross bracing of the suspended span and the weights of the cantilever arm needed to carry them have already been developed. It remains to calculate the weights of the laterals and of the cross bracing of the cantilever arm and the weights of the trusses needed to carry them. The wind pressure at the end of the cantilever arm comes from the suspended span end and is $p_{ws} \frac{l_s}{2}$.

The wind pressure per foot of bridge along the cantilever arm is $p_{wc} = a + bx$, where x is the distance in feet from the end of the cantilever arm.

$$p_{ws} = p_{ws}^t + p_{ws}^c = 900 + 1.4l_s \text{ for the heaviest loads.}$$

For lighter loads see equations (32) to (35).

The wind shear at the distance x from the end of the cantilever arm is

$$S_w^x = p_{ws} \frac{l_s}{2} + \int_0^x (a + bx) dx = p_{ws} \frac{l_s}{2} + \frac{x}{2} (2a + bx)$$

The wind moment at the distance Z from the end of the cantilever arm is

$$M_w^z = p_{ws} \frac{l_s}{2} Z + \int_0^z (Z - x) (a + bx) dx = p_{ws} \frac{l_s}{2} Z + \frac{aZ^2}{2} + \frac{bZ^3}{6}, \text{ or,}$$

$$\text{replacing } Z \text{ by } x, M_w^x = p_{ws} \frac{l_s}{2} x + \frac{x^2}{6} (3a + bx)$$

In very long spans of necessarily large width it is economical to place the railroad tracks far apart. In this case the loading of one track only produces, with top and bottom lateral systems, large stresses in the laterals and the cross bracing. These can be avoided by using only a bottom lateral system and by carrying the wind pressures acting above the bottom laterals to them by cross bracings at the intermediate posts. In this case the whole wind pressure must be carried by the bottom laterals.

The weight of the lateral system for a length dx at the distance x from the end of the cantilever arm is

$$dW_l = dW_{lch} + dW_{ld}$$

The lateral chord stress is

$$\frac{M_w^x}{B_r} = \frac{1}{B_r} \left\{ p_{ws} \frac{l_s}{2} x + \frac{x^2}{6} (3a + bx) \right\}$$

The weight of the length dx of both lateral chords is

$$dW_{lch} = \frac{6.8a_c}{B_r U_c} \left\{ p_{ws} \frac{l_s}{2} x + \frac{x^2}{6} (3a + bx) \right\} dx$$

With the usual double-system stiff diagonal laterals, the weight of the lateral diagonals is

$$dW_{ld} = \frac{6.8a_l}{U_l \sin 2\beta_l} \left\{ p_{ws} \frac{l_s}{2} + \frac{x}{2} (2a + bx) \right\} dx$$

$$\begin{aligned} \text{and } W_l &= \int_0^{lc} dW_{lch} + dW_{ld} \\ &= \frac{6.8a_c l_c^2}{24B_r U_c} \left\{ 6p_{ws} l_s + l_c (4a + bl_c) \right\} \\ &\quad + \frac{6.8a_l l_c}{6U_l \sin 2\beta_l} \left\{ 3p_{ws} l_s + l_c (3a + bl_c) \right\} \end{aligned}$$

The cross bracing weighs about twice as much as the lateral diagonals, or $W_{cb} = 2W_{ld}$, and $W_w = W_l + W_{cb}$.

Therefore

$$\begin{aligned} W_w &= \frac{6.8a_c l_c^2}{24B_r U_c} \left\{ 6p_{ws} l_s + l_c (4a + bl_c) \right\} \\ &\quad + \frac{3.4a_l l_c}{U_l \sin 2\beta_l} \left\{ 3p_{ws} l_s + l_c (3a + bl_c) \right\} \dots\dots\dots (53) \end{aligned}$$

This lateral system and cross bracing must be carried by a truss. The formulas for the successive dead loads and the weights of these trusses are derived in a similar manner as those for the moving load trusses. They are given in equations (54) to (58).

The floor of the cantilever arm is practically a uniform load per lineal foot of bridge; it must also be carried by a truss. The shear at the distance x from the end of the cantilever arm is $S_f^x = fx$. The moment at the distance x from the end of the cantilever arm is $M_f^x = \frac{fx^2}{2}$. The weight of the length dx at the distance x from the end of the truss carrying the floor is

$$\begin{aligned} dW_f &= V (AM_x + BS_x) dx \\ dW_f^{d_1} &= \frac{Vfx}{2} (Ax + 2B) dx \\ W_f^{d_1} &= \int_{x=0}^{x=l_c} dW_f^{d_1} = \frac{Vfl_c^2}{6} (Al_c + 3B) \dots\dots\dots (59) \end{aligned}$$

The weight of this truss is carried by a truss the weight of which is $W_f^{d_2}$ given in equation (60).

CANTILEVER ARMS WITH INCLINED CHORDS.

With straight inclined chords the height at the distance from the end of the cantilever arm is $h_x = a + bx$. The moment from the moving load μ per foot of bridge at the distance x from the end of the cantilever arm is $M_x = \mu \frac{x}{2} (x + l_s)$

The resulting chord stress is

$$\frac{\mu \cdot x (x + l_s) \sec \delta}{2 (bx + a)}$$

where δ is the angle of the chord with the horizontal.

The tension chord section is

$$\frac{\mu x (x + l_s) \sec \delta_t}{2 (bx + a) U_t}$$

The weight of the tension chord is for the span length dx

$$\frac{3.4\mu x (x + l_s) \alpha_t \sec^2 \delta_t}{2 (bx + a) U_t} \cdot dx$$

The weight of the whole tension chord for the load μ is

$$W_{ich} = \int_0^{l_c} \frac{3.4\mu a_t \sec^2 \delta_t \cdot x (x + l_s)}{2U_t (bx + a)} dx$$

$$\frac{x^2 + l_s x}{bx + a} = \frac{x}{b} + \frac{bl_s - a}{b^2} - \frac{a(bl_s - a)}{b^2(a + bx)}$$

$$\begin{aligned} \int_0^{l_c} dx \frac{x(x + l_s)}{bx + a} &= \int_0^{l_c} \left[\frac{x}{b} + \frac{bl_s - a}{b^2} - \frac{a(bl_s - a)}{b^2} \cdot \frac{1}{a + bx} \right] dx \\ &= \frac{l_c^2}{2b} + \frac{(bl_s - a)l_c}{b^2} - \frac{a(bl_s - a)}{b^3} \cdot l_n \cdot \frac{a + bl_c}{a} \end{aligned}$$

$a + bl_c = h_p$ = height at pier,

therefore $b = \frac{h_p - a}{l_c}$.

If $g_{t1} = \frac{3.4\mu a_t \sec^2 \delta_t}{2U_t}$ then

$$W_{i.t.ch} = g_{t1} l_c^3 \left\{ \frac{3h_p - 5a}{2(h_p - a)} - \frac{a(h_p - 2a)}{(h_p - a)^3} l_n \frac{h_p}{a} \right\}$$

$$\text{If } K_1 = \int_0^{l_c} \frac{x(x + l_s)}{bx + a} = l_c^3 \left\{ \frac{3h_p - 5a}{2(h_p - a)^2} - \frac{a(h_p - 2a)}{(h_p - a)^3} l_n \frac{h_p}{a} \right\}$$

then $W_{i.t.ch} = g_{t1} K_1$

$$W_{i.c.ch} = g_{c1} K_1$$

where $g_{c1} = \frac{3.4a_c \mu \sec^2 \delta_c}{2U_c}$

$W_{i.ch} = (g_{c1} + g_{t1}) K_1$ where $W_{i.ch}$ is the weight of the two chords of a cantilever arm required for the moving load μ .

Fully written out the last equation becomes:

$$\begin{aligned} W_{i.ch} &= l_c^3 \left\{ \frac{3h_p - 5a}{2(h_p - a)^2} - \frac{a(h_p - 2a)}{(h_p - a)^3} l_n \frac{h_p}{a} \right\} \times \frac{3.4\mu}{2} \\ &\quad \times \left\{ \frac{a_t \sec^2 \delta_t}{U_t} + \frac{a_c \sec^2 \delta_c}{U_c} \right\} \end{aligned}$$

For $l_n \frac{h_p}{a}$ we may also write $2.3026 \log \frac{h_p}{a}$.

The shear at the distance x from the end of the cantilever arm is $S_x = \mu \left(x + \frac{l_s}{2} \right)$. The shear is partly in the chords.

The shear in the two chords is

$$S_{ch}^x = \frac{\mu x (x + l_s)}{2 (bx + a)} (\tan \delta_t + \tan \delta_c)$$

$\tan \delta_t + \tan \delta_c = b$, therefore

$$S_{ch}^x = \frac{\mu bx (x + l_s)}{2 (bx + a)}$$

The shear in the web is, therefore,

$$S_{web}^x = S_x - S_{ch}^x = \mu \left\{ x + \frac{l_s}{2} - \frac{bx (x + l_s)}{2 (bx + a)} \right\}$$

The shear area of the web is

$$\begin{aligned} \int_0^{l_c} S_{web}^x dx &= \mu \int_0^{l_c} \left\{ x + \frac{l_s}{2} - b \frac{x (x + l_s)}{2 (bx + a)} \right\} dx \\ &= \frac{\mu}{2} \left\{ l_c (l_c + l_s) - bK_1 \right\} = S_{web}^a \end{aligned}$$

The weight of the web is

$$W_{i \cdot web} = BS_{web}^a + \text{pier post.}$$

The pier post, here assumed to be vertical, carries the shear of the top chord to the main pier.

The shear in the top chord of the cantilever arm at the pier is

$$\frac{\mu l_c (l_s + l_c) \tan \delta_t}{2 h_p}$$

The corresponding weight of the post is

$$\frac{3.4 \alpha_{\theta_2} \mu l_c (l_s + l_c) \tan \delta_t}{2 U_{c_2}}$$

The weight of the web is, therefore,

$$W_{i.web} = \frac{\mu}{2} B \left\{ l_c(l_c + l_s) - bK_1 \right\} + \frac{3.4 a_{c_2} \mu l_c (l_c + l_s) \tan \delta_t}{2 U_{c_2}}$$

and for $l_c = l_s$

$$W_{i.web} = \mu B \left\{ l_c^2 - \frac{b}{2} K_1 \right\} + \frac{3.4 a_{c_2} \mu l_c^2 \tan \delta_t}{U_{c_2}}$$

Where U_{c_2} is the unit stress for compression in the pier post.

To obtain the relative weight of the trusses of cantilever arms with inclined and with parallel chords we first calculate the weights of both kinds of trusses required for the moving load and impact stresses, and after this the weights of the two kinds of trusses required for the dead-load stresses.

The assumed moving loads are equivalent uniform loads per foot of bridge, the assumed dead loads are uniform for the suspended span, but increasing from the end of the cantilever arm toward the pier in a definite manner, approximating the increase in the actual dead loads.

We compare trusses with inclined chords of such heights at the end and the main pier as will give approximately the least weight of steel with trusses having parallel chords, and of such height as will give the same weight of chords as the trusses with inclined chords.

For very long spans the most economical suspended span has approximately the length of the cantilever arm; we therefore take for our comparison $l_s = l_c$.

$$\text{We also take } a = \frac{l_c}{9} \quad h_p = 4 \frac{1}{2} a = \frac{l_c}{2}.$$

$$\text{This gives } b = \frac{h_p - a}{l_c} = \frac{3.5}{9} = 0.3889.$$

$$\text{We obtain then } K_1 = 2.333 l_c^2.$$

If we take $\delta_c = \delta_t = \delta$ then

$$g_{c_1} + g_{t_1} = \frac{\mu \sec^2 \delta}{2} 3.4 \left(\frac{a_c}{U_c} + \frac{a_t}{U_t} \right)$$

$$W_{i.ch} = k_1 (g_{c_1} + g_{t_1}) = 1.1665 l_c^2 \mu \sec^2 \delta \times 3.4 \left(\frac{a_c}{U_c} + \frac{a_t}{U_t} \right)$$

For parallel chords we have

$$W_{p.ch} = \frac{5}{12} l_c^3 \mu A \quad \text{where } A = \frac{3.4}{h} \left(\frac{a_c}{U_c} + \frac{a_t}{U_t} \right)$$

To find what height h with parallel chords gives the same weight of chords as the heights a and $4\frac{1}{2}a$ at the end of the cantilever arm and at the pier we have

$$1.1665 \sec^2 \delta = \frac{5}{12} \frac{l_c}{h}$$

This gives
$$h = \frac{5l_c}{12 \times 1.1665 \sec^2 \delta}$$

$$\tan \delta = \frac{1.75}{9} = 0.19447 \sec^2 \delta = 1.038$$

$$h = \frac{l_c}{2.906} = 0.3441 l_c$$

The weight of the web with inclined chords is

$$\begin{aligned} W_{iweb} &= \mu B l_c^2 (1 - 0.1944 \times 2.333) \\ &\quad + \frac{3.4 \mu l_c^2 1.5 \times 0.1944}{19600} \\ &= \mu l_c^2 (0.546B + 0.0000506) \end{aligned}$$

19600 is the unit stress in the pier post; this assumes it to be of nickel steel of 1.4 times the strength of carbon steel, $\frac{l}{r} < 50$.

If we take the subdivided K system of web members we have

$$B_k = 3.75 \left(\frac{a_{t1}}{U_{t1}} + \frac{a_{c1}}{U_{c1}} \right) \left(\frac{1}{\sin 2\beta} + \frac{1}{2 \tan \beta} \right)$$

The angle β and U_{c1} vary. The weights near the pier are the most important. The values at the distance $\frac{l_c}{4}$ from the pier give approximately correct results.

The height at the distance $\frac{l_c}{4}$ from the pier is $0.4028 l_c$. The

diagonals go over two panels in half the height. Taking 12 panels, we have

$$\tan \beta = \frac{\frac{1}{3}l_c}{0.4028l_c} = 0.8274$$

$$\beta = 39^\circ 36' \quad 2\beta = 79^\circ 12'$$

$$\sin 2\beta = 0.9823$$

$$B_k = 3.75 \left(\frac{1.24}{28,000} + \frac{1.5}{17,000} \right) \times \left(\frac{1}{0.9823} + \frac{1}{1.6548} \right) = 0.000807$$

Therefore

$$W_i \cdot web = \mu l_c^2 (0.546 \times 0.000807 + 0.0000506)$$

$$W_i \cdot web = 0.000491 \mu l_c^2$$

For parallel chords we have

$$W_p \cdot web = B_k \mu l_c^2$$

Taking the height which makes the weights of the chords equal with parallel and inclined chords, we have $h = 0.3441 l_c$.

The diagonals of the subdivided K system go over half the height in two panels, therefore,

$$\tan \beta = \frac{0.3333}{0.3441} = 0.969$$

$$\beta = 44^\circ 6' \quad 2\beta = 88^\circ 12'$$

$$\sin 2\beta = 0.9995$$

$$B_k = 3.75 \left(\frac{1.24}{28,000} + \frac{1.5}{17,000} \right) \left(\frac{1}{0.9995} + \frac{1}{1.938} \right)$$

$$B_k = 0.000754$$

$$W_p \cdot web = 0.000754 \mu l_c^2$$

The difference in the weights of the webs for parallel and inclined chords is

$$\mu l_c^2 (0.000754 - 0.000491) = 0.000263 \mu l_c^2$$

This result needs correction, because the formula for the weight of the web includes not only the main web members but

also the subsidiary web members, like suspenders, top-chord supports, and the subsidiary diagonals from the sub- to the main panel points.

These were allowed for by changing the coefficient 3.4 to 3.75. The weight of these subsidiary members remains substantially the same with both parallel and inclined chords.

For this reason the value $0.000491\mu l_c^2$ should be increased by $\mu l_c^2 \left(0.000263 \times \frac{0.35}{3.75} \right) = 0.0000246\mu l_c^2$, which represents the reduction erroneously made by the formula in the weight of these subsidiary members. This gives for the correct weight

$$W_i \cdot web = (0.000491 + 0.0000246) \mu l_c^2 = 0.000516\mu l_c^2$$

The weight of the chords is

$$\begin{aligned} W_i \cdot ch &= 1.1665\mu l_c^2 \sec^2 \delta \times 3.4 \left(\frac{a_c}{U_c} + \frac{a_t}{U_t} \right) \\ &= 1.1665 \times 1.038 \times 3.4 \left(\frac{1.45}{18,700} + \frac{1.25}{28,000} \right) \mu l_c^2 \\ &= 1.1665 \times 1.038 \times 0.0004154 \mu l_c^2 \\ &= 0.000503\mu l_c^2 \end{aligned}$$

Eyebar top chords and nickel steel 1.4 times as strong as carbon steel were assumed. The combined weight of the chords and the webs is, with parallel chords,

$$\begin{aligned} W_p &= (0.000503 + 0.000754) \mu l_c^2 \\ &= 0.001257\mu l_c^2 \end{aligned}$$

For inclined chords,

$$W_i = (0.000503 + 0.000516) \mu l_c^2 = 0.001019\mu l_c^2$$

The ratio between the two weights is

$$\frac{W_i}{W_p} = \frac{0.001019}{0.001257} = 0.81$$

The weight of the cantilever trusses to carry the moving loads is, therefore, for inclined chords of the kind above described, 81 per cent. of the weight with parallel chords. This result is

very little modified if δ_c and δ_i are different without change in the heights. An increase of δ_i increases the weight of the pier post but reduces the sum of the weights of the chords.

When the load per foot is not uniform but increases toward the pier, the load at the end of the cantilever arm being P , the load per foot at the distance x from the end of the cantilever arm being $p + qx$, a loading similar to that from the wind, then

$$S_x = P + \frac{x}{2}(2p + qx)$$

$$M_x = Px + \frac{x^2}{6}(3p + qx)$$

With $h_x = a + bx$ the chord stress is

$$\frac{Px + \frac{x^2}{6}(3p + qx) \sec \delta}{a + bx}$$

The weight of the tension chord for the span length dx is

$$\begin{aligned} W_{i.t.ch} &= \frac{3.4 \cdot a_t \sec^2 \delta_t}{6U_t} \int_0^{l_c} \frac{qx^3 + 3px^2 + 6Px}{a + bx} dx \\ &\quad qx^3 + 3px^2 + 6Px : bx + a \\ &= \frac{qx^2}{b} + \frac{3bp - aq}{b^2} \cdot x + \frac{6Pb^2 - 3abp + a^2q}{b^3} \\ &\quad - a \frac{(6Pb^2 - 3abp + a^2q)}{b^3(bx + a)} \end{aligned}$$

$$\begin{aligned} \text{Therefore } &\int_0^{l_c} \frac{qx^3 + 3px^2 + 6Px}{a + bx} dx \\ &= \frac{ql_c^3}{3b} + \frac{(3bp - aq)}{2b^2} \cdot l_c^2 + \frac{6(Pb^2 - 3abp + a^2q)}{6^3} l_c \\ &\quad - \frac{a(6Pb^2 - 3abp + a^2q)}{b^4} l_n \frac{a + bl_c}{a} \end{aligned}$$

We have, therefore, for the weight of the inclined tension chord carrying the dead load,

$$W_{i.t.ch} = g_t \cdot \frac{1}{3} \left\{ \frac{ql_c^2}{3b} + \frac{3bp - aq}{2b^2} l_c^2 + \frac{6Pb^2 - 3abp + a^2q}{b^4} \right. \\ \left. \left(bl_c - al_n \frac{hp}{a} \right) \right\}$$

$$\text{If } K = \frac{1}{3} \left\{ \frac{ql_c^2}{3b} + \frac{(3bp - aq) l_c^2}{2b^2} + \frac{6Pb^2 - 3abp + a^2q}{b^4} \right. \\ \left. \times \left(bl_c - 2.3026a \log \frac{hp}{a} \right) \right\}$$

$$\text{Then } W_{i.t.ch} = g_t K$$

$$\text{and } \frac{W_{i.c.ch} = g_c K}{W_{ich} = (g_t + g_c) K}$$

$$\text{where } g_t = \frac{3.4a_t \sec^2 \delta_t}{2U_t} \cdot g_c = \frac{3.4a_c \sec^2 \delta_c}{2U_c}$$

The shear at the distance x from the end of the cantilever arm is

$$S_x = P + \frac{x}{2} (2p + qx)$$

This shear is partly in the chords. The shear in the two chords is

$$\frac{Px + \frac{x^2}{6} (3p + qx)}{a + bx} b$$

The shear in the web is, therefore,

$$S_{web}^x = S_x - S_{ch} = P + \frac{x}{2} (2p + qx) - \frac{(qx^3 + 3px^2 + 6Px)}{6(a + bx)} b$$

The shear area of the web is

$$\int_0^{lc} S_{web}^x dx = \int_0^{lc} \left\{ P + \frac{x}{2} (2p + qx) - \frac{(qx^3 + 3px^2 + 6Px) b}{6(a + bx)} \right\} dx$$

$$(bqx^3 + 3bpx^2 + 5bPx) : (bx + a) = qx^2 + \frac{3bp - aq}{b} x$$

$$+ \frac{6Pb^2 - 3abp + a^2q}{b^2} - \frac{a(6Pb^2 - 3abp + a^2q)}{b^3(a+bx)}$$

$$\int_0^{l_c} S_{web}^x dx = Pl_c + \frac{pl_c^2}{2} + \frac{ql_c^3}{6}$$

$$- \frac{1}{6} \left[\frac{q}{3} l_c^3 + \frac{3bp - aq}{2b} l_c^2 + \frac{6Pb^2 - 3abp + a^2q}{b^3} \times \left(bl_c - al_n \frac{h_p}{a} \right) \right]$$

The weight of the web is

$$W_{i\ web} = B \left[\int_0^{l_c} S_{web}^x dx \right] + \text{pier post.}$$

The pier post not included in the first part carries the vertical component of the top-chord stress to the pier.

For the top-chord stress at the pier we have the moment

$$M_{l_c} = Pl_c + \frac{l_c^2}{6} (3p + ql_c)$$

The vertical component of the stress is

$$\frac{\left\{ Pl_c + \frac{l_c^2}{6} (3p + ql_c) \right\} \tan \delta_t}{h_p}$$

The weight of the post is

$$\frac{\left\{ Pl_c + \frac{l_c^2}{6} (3p + ql_c) \right\} \alpha_{c_2} \tan \delta_t}{U_{c_2}}$$

We have, therefore,

$$W_{i\ web} = B \left\{ \frac{l_c}{6} (6P + 3pl_c + ql_c^2) - \frac{b}{2} K \right\}$$

$$+ \frac{l_c (6P + 3pl_c + ql_c^2) \alpha_{c_2} \tan \delta_t}{6U_{c_2}}$$

We are now prepared to find the ratio of the weights of the trusses for the dead loads, with inclined and with parallel chords.

We take for this purpose the same shape of trusses as we used in the comparison of the trusses for the moving and impact loads.

Taking $l_s = l_c = \frac{L}{3}$ and $P = \frac{pl_s}{2}$, also $a + bl_c = 4.5a = h_p$ and $p + ql_c = 4.5p$

$$a = \frac{l_c}{9} \text{ therefore } b = \frac{3.5}{9} = 0.3889 \quad q = \frac{3.5p}{l_c}$$

Expressing P , q and a by p and l_c we obtain

$$K = \frac{pl_c^2}{3} \left\{ 3 + \frac{9}{3.5} + \frac{8.5 \times 9^2}{3.5^3} \left(\frac{3.5}{9} - \frac{2.3026}{9} \log 4.5 \right) \right\}$$

$$K = pl_c^2 \left\{ 1 + \frac{3}{3.5} + \frac{25.5}{3.5^3} (3.5 - 2.3026 \log 4.5) \right\}$$

$$K = 3.0444 pl_c^2$$

$$\text{If } \delta_c = \delta_t = \delta \text{ then } g_c + g_t = \frac{3.4 \sec^2 \delta}{2} \left(\frac{a_c}{U_c} + \frac{a_t}{U_t} \right)$$

$$\text{If } U_t = 28,000 \quad U_c = 18,700$$

$$\tan \delta_t = \frac{b}{2} = \frac{1.75}{9} = 0.1944$$

$$\tan^2 \delta_t = 0.038 \quad \sec^2 \delta_t = 1.038$$

$$\text{we obtain } a_c = 1.45 \quad a_t = 1.25$$

$$g_c + g_t = 1.7 \times 1.038 \left(\frac{1.45}{18,700} + \frac{1.25}{28,000} \right)$$

$$g_c + g_t = 0.0002156$$

$$W_{ich}^d = 0.0002156 \times 3.0444 pl_c^2$$

$$= 0.0006564 pl_c^2$$

For the weight of the web we have

$$W_{iweb}^d = B \left\{ \frac{l_c}{6} (6P + 3pl_c + ql_c^2) - \frac{b}{2} K \right\} \\ + \frac{l_c}{6} (6P + 3pl_c + ql_c^2) \frac{a_{c2} \tan \delta_t}{U_{c2}}$$

$$\begin{aligned}
&= 0.000807 \left\{ \frac{pl_c^2}{6} (3 + 3 + 3 \cdot 5) - 0.1944 \times 3.0444 pl_c^2 \right\} \\
&\quad + 1.5833 pl_c^2 \frac{1.75}{9} \times 1.5 \\
&\quad \quad \quad \frac{19,600}{19,600} \\
&= 0.000824 pl_c^2 \text{ subject to a slight correction.}
\end{aligned}$$

For parallel chords we have

$$M_x = Px + \frac{x^2}{6} (3p + qx)$$

$$S_x = P + \frac{x}{2} (2p + qx)$$

$$dW_p^d = (AM_x + BS_x) dx$$

$$= \left\{ APx + \frac{Ax^2}{6} (3p + qx) + BP + B \frac{x}{2} (2p + qx) \right\} dx$$

$$= \left\{ \frac{Aqx^3}{6} + (Ap + Bq) \frac{x^2}{2} + (AP + Bp)x + BP \right\} dx$$

$$\begin{aligned}
W_p^d &= \int_0^{l_c} dW_p^d = \frac{l_c^2}{24} \left\{ Aql_c^2 + (Ap + Bq) 4l_c + \right. \\
&\quad \left. 12 (AP + Bp) + \frac{24BP}{l_c} \right\}
\end{aligned}$$

$$A = \frac{3.4}{206.4} \left(\frac{1.45}{18,700} + \frac{1.25}{28,000} \right) = 2013 \times 10^{-9}$$

$$B_k = 0.000754$$

Introducing in the equation for W_p^d

$$P = \frac{pl_c}{2}, \quad q = \frac{3.5p}{l_c}$$

we obtain, after reduction,

$$W_p^d = \frac{pl_c^2}{24} (13.5 Al_c + 38B)$$

In this equation the part with the factor A gives the weight of

the chord, that with the factor B gives the weight of the web. We obtain for the web with K system

$$W_p^d{}_{web} = \frac{pl_c^2}{24} \times 0.000754 \times 38 = 0.001194 pl_c^2$$

We found for the web with inclined chords $0.000824 pl_c^2$. The difference is $0.000370 pl_c^2$.

The required correction for the inclined web is

$$\begin{aligned} & 0.00037 \times \frac{35}{375} pl_c^2 \\ & = 0.000034 pl_c^2 \end{aligned}$$

This gives for the corrected value of $W_{i.web}^d = 0.000824$
 $+ \frac{0.000034}{0.000858}$

Adding the weight of the chords we obtain

$$W_i^d = pl_c^2 (0.000858 + 0.000656)$$

$$\text{or } W_i^d = 0.001514 pl_c^2$$

For W_p^d we find with $l_c = 600$ feet

$$\begin{aligned} W_p^d &= \frac{pl_c^2}{24} (13.5 \times 2013 \times 10^{-9} \times 600 + 38 \times 0.000754) \\ &= 0.001873 pl_c^2 \end{aligned}$$

$$\text{and } \frac{W_c^d}{W_p^d} = \frac{0.001514}{0.001873} = 0.808$$

This ratio is, therefore, practically the same for loads uniformly distributed and for loads distributed like the dead loads.

The coefficient for cantilever arms of larger end height suitable for erection of the suspended span by building out from the ends of the cantilever arms were obtained in exactly the same manner.

All the foregoing formulas give either the weight of two trusses each with half the load or of one truss carrying the whole load.

SOME PRESENT-DAY METALLURGICAL PROBLEMS.*

BY

D. A. LYON, A.M.,

Metallurgist, U. S. Bureau of Mines.

METALLURGY is commonly defined as the art of extracting metals from their ores. If we look up the definition of the word "art," we find it stated that by art is meant the employment of means to the accomplishment of some end; a system of rules and established methods to facilitate the performance of certain actions; familiarity with such principles and skill in applying them to an end or purpose, as of a practical, useful, or technical character. If we apply this definition to metallurgy, we may say that metallurgy is the employment of chemistry to the accomplishment of extracting metals from their ores; in other words, metallurgy is applied chemistry, and that, by reason of a long period of application, a system of rules and established methods have been worked out in order to facilitate the performance of certain actions, or reactions, and that a metallurgist is one who is familiar with such methods and skilled in applying them to accomplish the end that he may desire.

Although metallurgy is applied chemistry, it is nevertheless true that metallurgy was the forerunner of chemistry, and is a very ancient art. As is evidenced by the large number of flint instruments which have been discovered from time to time, and in different localities, and which are now to be found in various museums throughout the world, there was a time when metals were entirely unknown, or else had been produced in such small quantities as to prohibit their general use. However, as time went on, men acquired the art of reducing the less refractory metals from their ores. Since copper was one of the first metals to be used, it may be that the copper came from what are known as native deposits, and that later the art of reducing it and other less refractory metals was discovered. Be that as it may, the

* Presented at the meeting of the Mining and Metallurgical Section, held Thursday, December 4, 1913.

copper, being soft, had to be hardened, and in ancient times, as to-day, this was done by the addition of a small proportion of iron, arsenic, or tin. At just what period the use of iron became general we do not know, for, due to the rapidity with which it oxidizes and likewise due to the fact that oxidation gradually proceeds through the whole mass, an iron instrument left lying alongside of a flint instrument would wholly disappear, and so it may be that iron was used much earlier than we have any record of. However, we are informed that explorers in Egypt and in Assyria discovered specimens of brass and iron which show that the Egyptians were acquainted with the use of iron as much as 4000 years ago, and possibly even before that time. In the early books of the Old Testament frequent references are made to the use of iron, and so, as before stated, we have every reason to believe that the use of iron was known in very early times. However, for centuries and centuries, metallurgy was more of a craft than an art, and new discoveries were for the most part the result of accident rather than of investigation. During the Middle Ages alchemy came into vogue, the principal aim of which, we are told, was to discover ways and means for the transmuting of base metals into gold. Although the alchemists were unsuccessful in their attempts, they nevertheless accumulated a large amount of facts on which was based the modern science of chemistry, but it was not until about a century ago that the later science was advanced to anything like its present state of development, and it has only been within that time that metallurgical processes have been carried out on a really scientific basis. As a matter of fact, the advances have been so rapid that the metallurgical profession has come to feel pretty well satisfied with itself. This is due to the fact that a large part of the advancement which has been made has been in the nature of large production at comparatively low costs.

I do not wish to be understood, in this connection, as inferring that present-day metallurgical practice has not been developed along perfectly normal lines; as a matter of fact, it has, but, now that it has reached its present state of development, the metallurgical profession should, and is, turning its attention to perfecting those processes which are in use at the present time, to devising others which will correct existing defects, and to solving some of the many problems which require a solution.

PROBLEMS CONNECTED WITH THE METALLURGY OF IRON
AND STEEL.*Use of Inferior Grades of Ores.*

Although we have heard more or less, during recent years, of the possibility of the world's iron ore supplies becoming exhausted, those who have made a special study of the subject inform us that they do not see any immediate prospect of this being the case. New ore fields are discovered almost every year, as, for example, those deposits in Brazil, a description of which was contributed to the International Geological Congress in 1910 by Dr. Derby, of the Brazilian Geological Survey, and which, according to Dr. C. K. Leith¹ and others, is greater than any deposit which has been discovered in the past, and whose ores are even of higher grade than those of the Lake Superior region. However, though it is true that the world's visible iron ore supply has been added to in this manner, it is equally true that the iron industry is beginning to feel the necessity of turning its attention to the treatment of ores which in the past have not been considered suitable for blast-furnace work, as, for example, those deposits which are found to the western end of the Mesabi Range, where the ore is interbedded with sand. These deposits are very extensive and for a long time they were not considered very valuable. They are now successfully concentrated, and so these deposits have added enormously to the value and extent of the Mesabi reserves. This is also true of many other deposits; namely, that, although too lean to work as raw ores, it is possible by concentration to bring the metallic content of the concentrates up to a point where they correspond to a fairly good ore. Although the metallurgical treatment of such ores requires special care and attention, due to the physical nature of the same, the smelting of them does not present any particularly difficult problems, as do those ores in which the iron is combined, either mechanically or chemically, with some other element or elements, and from which the iron is separated with difficulty, either by mechanical methods or in the metallurgical treatment of the same.

¹ "Economic Geology," vol. vi, 1911, p. 670.

CLASSIFICATION OF IRON ORES.

The ores of iron which are used in the production of iron may be arranged according to the following general classification, as given by Turner:²

I. Magnetic oxide or magnetite.

(a) Pure magnetites (FeO , Fe_2O_3 , Fe_3O_4).

(b) Magnetites in which part of the oxide of iron has been replaced by the oxide of another metal, *e.g.*, chromium (chromite), titanium (ilmenite), or zinc (franklinite).

II. Ferric oxide or hæmatite.

(a) Anhydrous ferric oxide or red hæmatite (Fe_2O_3).

(b) Hydrated ferric oxide, including brown hæmatite, limonite, bog ore, etc.

III. Ferrous carbonate or spathic ores.

(a) Pure spathic ores.

(b) Carbonate ores associated with clay (clay iron stones, argillaceous ores) or with bituminous matter (blackband).

As stated, these are the ores that are used in the production of iron. The majority of ores which have heretofore been treated in this country belong to II (a) more or less mixed with those of (b). For some time, iron ores of I (a), magnetites, were looked upon with disfavor, even when pure, as being difficult to reduce. The main objection to them, however, has been that they are so often mixed with other impurities, such as silica, titanium, and phosphorus. Silica, of course, if in excess, simply renders the iron too low in iron content to permit of profitable working; if too high in phosphorus, the iron will not make good steel, and if too high in titanium, the general impression has been that in smelting the ores in the blast furnace sticky slags were produced which interfered with the successful working of the furnace. As to the latter point, the same will be discussed farther along in this paper. On the whole, then, we may say, so far as the subject of ores is concerned, that the problem which immediately concerns the iron metallurgist is the treatment of the complex ores, so to speak,—that is, ores containing

² "The Metallurgy of Iron," by T. Turner, p. 50.

other metallic elements, and which are considered harmful for either of the following reasons:

(1) In the treatment of the ores in the blast furnace the other elements present in the ore may be reduced with the iron and so impart to it undesirable properties.

(2) As in the case of titanium ores, the titanium may render the treatment of the ores difficult, for reasons already explained.

As to the first of these problems, namely, the imparting to the iron of undesirable properties by an alloying element, it is now realized that certain elements which are present in iron ores impart beneficial rather than harmful effects to the fabricated metal. Take, for example, such ores as those of the Moa deposit in Cuba. They carry from 1.5 to 2 per cent. chromium, about half as much nickel, and 8.0 to 12 per cent. alumina. Although the treatment of such an ore is difficult in the blast furnace, and the steel maker is confronted with certain problems in converting the pig iron into steel, it is up to the metallurgist to conserve these two alloying elements, for alloy steels are now being used more and more, and in case of the Moa deposit it would seem as if there already existed in Nature a combination of elements in the same ore which have proved so beneficial in steel making. As stated by Dr. C. L. Parsons in Bulletin No. 47 of the U. S. Bureau of Mines, "the metallurgy of iron has reached a perfection beyond that of any other metal, and wastes have been eliminated to an extent that serves as some indication of what, perhaps, may be done in other industries when the same intelligent investigation has been applied." If this be true, then it would seem that progress in the metallurgy of iron and steel must be largely along the lines of conservation. However, it must not be inferred from such a statement that conservation has not been taken into account in the industry, for the saving and use of by-products testifies to that, as, for example, the making of a large part of the Portland cement of the country from blast furnace slags, etc. There is, however, still room for conservation, and especially along the lines of the conservation of those elements which are present in ores which have not been treated in the past, as there was no necessity of so doing, with the large supply of pure ores available, such as those of the Lake Superior region. It seems to the writer that one of the greatest problems in conservation, so far as the production of

iron is concerned, is the devising of some process whereby the iron which is associated with copper, lead, zinc, etc., in their ores may be saved instead of being thrown over the dump in the form of slag. Take, for example, the amount of iron that goes over the dump at Great Falls and Anaconda, Montana. At Great Falls it amounts to approximately 300 tons per day. At Anaconda it is about two and one-half or three times as much as this. At present this iron is lost, so far as its use as a metal is concerned. This is only one of the many plants of the country where the same thing takes place daily. We must, of course, admit that this iron plays its part in the smelting operations,—namely, as a basic neutralizing agent for the acid materials present in the charge,—and the problem, therefore, resolves itself into finding a suitable non-metallic base which will do the same work as the iron does, and a process whereby the iron may be saved and utilized. We must also admit, as has been pointed out by Mr. Wheeler, superintendent of the Boston and Montana Smelter at Great Falls, that, even if this iron could be recovered as metallic iron, it might be difficult to find a market for it in that region. However, that part of the difficulty would, no doubt, be overcome if a method could be found for recovering the iron.

If this iron should be alloyed with copper, perhaps all the better, as recent investigations tend to show that copper, when present in iron in proper proportions, inhibits corrosion. The writer is well aware that there are certain investigators who claim that such is not the case,—that is, that copper does not prevent corrosion, and that the purer iron is, the less liable it is to be corroded. With due deference to all those who hold this opinion, the writer believes that there is more evidence to warrant the belief that the presence of copper in proper amounts in steel does prevent corrosion, rather than that it does not, or, as some claim, by reason of its being an impurity, promotes it.

THE USE OF TITANIFEROUS ORES.

At the present time there is more or less prejudice among blast-furnace men against ores containing titanium oxide (TiO_2). Briefly stated, the history of the treatment of titanic ores is as follows: Numerous laboratory investigations have been conducted upon synthetic slags,³ and small commercial blast furnaces

³ By Rossi, Cox, Lennox, Stanley, Smolensky, and others.

have been operated upon titanium ores in Norway in 1850, at Norton, England, in 1868, and later by the McIntyre Furnaces in New York. In this connection it is well to note that all successful smelting of titanium iron ores has been done in small furnaces,—that is, furnaces having a daily capacity of from 3 to 15 tons of iron. The objections advanced by blast-furnace men of to-day against using titanium ores is that, when smelting ores containing even less than 1 per cent. of titanitic acid, cyanonitride collects in the hearth and soon necessitates the closing down of the furnace. In no instance in the operation of the small furnaces was trouble reported from accretions of cyanonitride, and in no instance was it found impossible to make a fluid slag. At Norton, England, both coke and charcoal were employed at different times. Rossi used coke. As to why the small furnaces were not bothered with accretions of cyanonitride was probably due to the fact that the temperature was too low to form the carbide of titanium, which in combination with the nitrogen of the blast at the tuyères forms cyanonitride. The problem, then, of smelting these ores in the modern blast furnace is seemingly one of duplicating the temperature conditions of the small furnaces that have proved successful. On the other hand, there are metallurgists who state that it is quite easy and perfectly feasible to smelt titanium ores in the modern blast furnace, and operated in the same manner as when treating simple ores,—that is, the charge is made up with such a proportion of ores, fluxes, and fuel as to give a fluid slag,—and it is further stated that it is an ill-founded notion that titanitic slags are viscous. Due to this diversity of opinion among iron blast-furnace men, the McIntyre Iron Company, which has large titaniferous ore holdings in New York State, has decided to carry on some experiments on a commercial scale at the plant of the Northern Iron Company at Port Henry, New York State. It is hoped, as a result of these experiments, to be able to dispel the uncertainties which now exist as regards the possibilities of being able to successfully smelt titanium ores. For this reason, it is expected that the experiments at Port Henry will be watched with a great deal of interest.

Thus we see that in the iron industry, so far as the use of raw materials is concerned, the problem of the metallurgist is:

(1) To so modify existing processes or invent new ones as

to enable him to successfully treat, from a commercial standpoint, those ores which have not hitherto been considered as suited to blast-furnace practice.

(2) To recover and make use of, as a source of iron, the vast amount of iron that is now thrown over the dump in the slags which are obtained in non-ferrous blast-furnace work.

(3) To prevent, if possible, the corrosion of the iron that is produced, either by the addition to it of some element which will inhibit corrosion, or by the production of a pure metal, which, as before stated, is the way some claim to be able to prevent corrosion. One of the greatest advances which could be made in conservation would be the discovery of some means whereby the corrosion of iron and steel could be prevented. Not only would this mean conservation of iron but of coal. If we calculate the amount of fuel that is used for all purposes, including transportation, installation, etc., we find that it amounts to about three tons of coal for every ton of pig iron produced. In collecting data on this subject, Dr. G. A. Hulett, Chief Chemist of the Bureau of Mines, plotted the data, and drew a curve, representing the production of pig iron in every five years since 1880. Multiplying these values by three, we get the tons of coal used in making this iron. The rate of production of pig iron in the United States for the last 25 years gives a steep curve, but the rate of increase of coal utilized for this purpose gives a curve three times as steep, and the results are most striking. The following table by Dr. Hulett indicates the situation:

TABLE I.

Date.	Million metric tons of pig iron.	Coal.
1880	3.2	9.6
1885	4.6	13.8
1890	6.8	20.4
1895	10.0	30.0
1900	14.0	42.0
1905	19.4	58.2
1910	26.0	78.0
1915	33.5	100.0
1920	41.5	124.5

The facts and curves presented by Dr. Hulett show the very great importance, even from this standpoint, of doing work

which will prevent the corrosion of iron and steel. As pointed out by him, no consideration has been given to the amount of labor used in producing the iron and steel, or interest on the capital invested in these operations; so that this is only one phase of the importance of the question of corrosion.

As regards conservation, although the amount of iron and steel which has been produced each year has steadily increased, less ore is now required to produce a ton of steel than was the case, say, in 1890, when nearly four tons of ore were consumed per ton of steel produced, whereas ten years later only 2.7 tons were required, and in 1910 only 2.1 tons. As pointed out by Chamberlain,⁴ though several factors are involved, this decrease in the amount of ore used has been due to the growth of the open-hearth process and the consequent utilization of scrap.

FINE ORES.

As is well known, it is only within recent years that this problem has arisen in iron blast-furnace work, for so long as only Lake Superior ores were used there was not much trouble from this source. However, as the richer ores began to grow scarcer, the poorer ones began to be concentrated, until now it is stated that there are over a million tons thus produced annually in the State of New York alone by magnetic concentration. Meanwhile, as before stated, the concentration by washing of the lean and sandy ores of the Mesabi range has increased until the amount of concentrates so produced is something over three million tons annually. Naturally the treatment of these concentrates in the blast furnace has greatly increased the percentage of fines in the burdening of the furnace, with the result that the furnaces are more difficult to operate than when treating coarser ores. Such being the case, it would seem that some preliminary treatment of these fines, for the purpose of agglomerating them, as well as the flue dust which is produced, would tend to increase the efficiency of the blast furnace. Inasmuch as considerable progress has already been made along this line,—that is, in the way of nodulizing and sintering fine ores,—it may not be strictly correct to speak of the treatment of fine ores in this manner as

⁴G. D. Chamberlain, "Some Developments of the Iron and Steel Industry," *Journal of Industrial and Engineering Chemistry*, vol. v, May, 1913.

a metallurgical problem. Be that as it may, there is, no doubt, considerable room for study along these lines, especially as regards the physical characteristics and the chemical composition of the agglomerated or sintered material, and the effect which the use of these materials has on the efficiency of the furnace.

PROBLEMS CONNECTED WITH THE OPERATION OF AN IRON
BLAST FURNACE.

Turning now to the operation of the blast furnace, although, as previously stated, the metallurgy of iron has reached a perfection beyond that of any other metal, there are still many problems to be solved in connection with the operation of the same, many of which are mechanical as well as metallurgical. For example, Mr. James Gayley discovered and proved some eight years ago that the use of a dry blast in blast-furnace work greatly increased the efficiency of the furnace. Although, so far as the writer is aware, it is not doubted that the use of the dry blast will greatly increase the efficiency of a furnace, nevertheless its use has not become so general as was predicted, and this, I should say, is due to the fact that the cost of installation of the Gayley system is quite heavy. If this be true,—namely, that the use of the dry blast does increase the efficiency of the furnace, but that its adoption has not become general on account of the cost of installing it, or for some other reason,—then the problem resolves itself into that of being able to accomplish the same results by some other means. In addition to the problem of the use of the dry blast, there are many others, which we will not attempt to discuss fully, but which may be stated as follows:

(a) Production of uniform grades,—*i.e.*, less of off-grade iron.

(b) Economy in coke,—*i.e.*, by making coke that is put into the furnace do more work, either in the smelting process itself, or by increasing the efficiency of the hot blast stove, or by some other means.

Some interesting work has recently been done along this line at a blast furnace in Belgium. Not only do they dry the blast, but they have also increased its oxygen content from 20.8 per cent. to 23.0 per cent. The oxygen is obtained from liquid air. After separating the oxygen from the more volatile gases,

the oxygen is finally compressed in holders and used as desired. The enrichment of the blast in this manner is not a new idea. J. E. Johnson obtained patents on a process of this kind in 1908, and has since given the matter more or less thought.

(c) A further utilization of the slag.

As is well known, iron blast-furnace slags are now used in making a large proportion of the Portland cement which is manufactured in this country. However, there is still a large part of it which is put to no better use than ballast for railroads, or for road-making, for which some other material can just as well be used, and so there is still room for a further study of the possible use of iron blast-furnace slags.

THE USE OF THE ELECTRIC FURNACE IN THE PRODUCTION OF IRON FROM ITS ORES.

As is well known, the electric furnace was not evolved in the hopes of competing with the blast furnace, but of finding a furnace and a process which would be able to produce iron in those localities where blast-furnace practice was not feasible, or, as in Sweden, where the cost of blast-furnace fuel was becoming so great as to cause the existing blast-furnace practice to become prohibitive.

DIFFICULTIES THAT HAD TO BE OVERCOME.

The idea of those who first took up the work was to construct a shaft similar to a blast-furnace shaft, and to then substitute electrodes for tuyères. When this was tried out in practice it was found that the life of the furnace wall in the neighborhood of the electrodes was short-lived, and no amount of water-cooling served to obviate this difficulty, but rather increased it if anything, due to jackets burning out, etc. As was early observed by Heroult, the proper way to maintain the walls of an electric furnace crucible is to get the electrodes as far removed from the side walls as possible, and in the development of the electric iron reduction furnace in California and in Sweden it was found not only necessary to do this but also to keep the charge as far as possible from the roof of the crucible, for unless this was done the roof was short-lived, due to the intense local heat which is generated at the point where the electrodes enter the charge. The maintenance of the roof of the crucible was one of the most

serious difficulties that had to be overcome, and in overcoming this difficulty the present shape of the roof of the crucible and the manner in which the electrodes are introduced into the crucible were evolved. As a further protection to the roof of the crucible a part of the gases escaping from the top of the shaft were returned to the crucible in order to cool the same, as well as to assist in the reduction of the charge.

THE ELECTRODE PROBLEM.

Although the Swedish experimenters did not have so much to contend with in this respect, in California the difficulty in securing electrodes that would meet the requirements greatly interfered with the progress of the work. When the latter was begun in California the manufacturers of electrodes in this country had not previously been called upon to furnish electrodes of such large cross section, namely, about 20 inches square and about 72 inches in length. Of those first furnished, that part of the electrode projecting into the crucible would either break off completely after it became heated up, or else large chunks would spall off from it, and, as can be readily imagined, these broken pieces gave no end of trouble in operating the furnace. That others also encountered this difficulty is evident from the following quotation from a paper presented by William R. Walker at a meeting of the American Iron and Steel Institute in 1912:

“Our problems, mechanical, metallurgical, and otherwise, proved many, and our experience soon demonstrated that the conditions surrounding the successful operation of a large electric furnace were in many respects entirely different from those involved in the use of smaller units. In illustration, the demands of a 15-ton electric furnace proved to be far in advance of the art of manufacturing electrodes. Our necessities represented a requirement that the electrode manufacturers of America and Europe had not been called upon to meet, and it took much time and money before there was finally accomplished the 20-inch round amorphous carbon electrode, and that is now being used at South Chicago.”

At the plant of the Noble Electric Steel Company it was finally decided to try graphite electrodes. These worked very satisfactorily in all respects except for the fact that on account of the angle at which it was necessary to insert them in the cru-

cible, due to the manner in which the furnace was constructed, they were subjected to a severe strain which caused them to break at the threaded joints. The electrode problem is, however, no longer a serious matter. As stated by Mr. Walker in his paper, the 20-inch round electrodes now in use at South Chicago give satisfaction, and at Trollhättan the large carbon electrodes of about the same size as those used at South Chicago meet the requirements.

PROBLEMS YET TO BE SOLVED IN CONNECTION WITH IRON
ELECTRIC FURNACE WORK.

Reduction in Shaft of Furnace.

In an ordinary blast furnace the weight of the gases produced exceeds the weight of the charge by 30 to 50 per cent., whereas in electric reduction furnace work the gases evolved amount to only about 40 per cent. by weight of the charge. In other words, in the blast furnace in the production of one ton of iron there is three to four times as much gas given off as there is in the production of one ton of iron in the electric furnace. Moreover, the temperature of the gas as it leaves the tuyères may be as much as 1600° C., whereas the highest temperature stated to have been attained at the lower end of the stack in the work at Trollhättan is 985° C. Even if this be granted, and that the temperature of the gas as it enters the stack may have as high a temperature as 1000° C., as pointed out by Frick, "inasmuch as the weight of the gases produced is only 35 to 45 per cent. of the weight of the charge, the charge would not be heated to more than about 350° C., due to the fact that the specific heat of the gas and that of the charge are about the same." Thus we see that we cannot expect complete reduction in the shaft if we depend solely upon the heat from the gases which are generated in the regular manner. In other words, the shaft acts merely as a preheater, with possibly a small amount of reduction taking place therein, but for the most part reduction takes place in the crucible by means of solid carbon.

Thus we see that an electric furnace may be operated in one of two ways:

(1) Reduction of the ore in the crucible by means of solid carbon, with no attempt at reduction in the stack, as is done in California at the present time by the Noble Electric Steel Company.

(2) Partial or complete reduction in the stack, this being the idea on which the Swedish furnaces are operated.

As we all know, that which may theoretically be best is not always so in practice. In this instance we are not able to judge by results, as we have not enough accumulated data at our disposal, and so can look at the matter only from a theoretical standpoint.

Theoretically,⁵ reduction should take place in the shaft of the electric iron reduction furnace. The problem, therefore, that presents itself is how best to accomplish this; that is, to so operate the furnace as to cause the oxide of iron to be reduced by the time it reaches the electrodes, so that the electric energy shall be called upon to furnish only enough heat to melt the sponge iron, to scorify the gangue materials and fluxes, and to furnish to the products of the furnace the heat necessary for their separation and removal from their furnace.

Among other problems that yet remain to be solved in connection with electric iron furnace work may be mentioned:

1. *The Size of the Unit.*—The electric reduction furnaces now in operation vary in size, as regards their horsepower, from 1500 up to 3500, while the largest yet designed by A. B. Elektrometall (of Sweden) is 7500 kilowatts. As can be readily understood, it is quite important that the size of the unit be made as large as possible, and the writer is of the opinion that no one is prepared to say at the present time just what that size will ultimately be.

2. *Efficiency of the Furnace.*—The efficiency of the furnace will also be increased as time goes on, and probably by improvements along the following lines:

- (a) The utilization of the waste gases.
- (b) The securing of a high-power factor.
- (c) The correction of induction losses.
- (d) The further study of the single-phase furnace *vs.* the three-phase furnace.

As regards the latter, inasmuch as practically all large power installations are three-phase, it would seem that the only logical thing to do is to use three-phase current in electric furnace work,

⁵ A theoretical discussion of this subject is given by the author in a paper, "Reduction of Iron Ores in the Electric Furnace," original communication to Eighth International Congress of Applied Chemistry, vol. xxvi, p. 519.

but from data submitted by Catani ⁶ it would seem as if the monophase furnace is more efficient than the polyphase furnace.

3. *The Use of Coke and Crude Oil as Reducing Agents.*—As is well known, of the coke charged into an iron blast furnace, only about two-thirds of the same is used for producing the heat necessary for carrying on the process, while the other one-third is used as a reducing agent. Therefore, if the electric furnace is used for the smelting of iron ores, only enough carbon has to be supplied to unite with the oxygen of the ore; in other words, to reduce it. So far only coke and charcoal have been tried to any extent as reducing agents in the reduction of iron ores in the electric furnace, and of these only charcoal has proven satisfactory. This has been shown by repeated trial runs at Trollhättan, and has been forcibly demonstrated by the fact that the plant at Hardanger, Norway, where coke was used as a reducing agent, after being in operation for about nine months, was forced to close down, due to the fact that nowhere near the same amount of pig iron could be produced per kilowatt-year of electrical energy expended as can be produced when charcoal is used. That this is true is doubtless due to the fact that coke is a much better conductor of electricity than is charcoal, especially after it becomes hot. For this reason, when using coke, the resistance of the charge becomes lowered, and, as the smelting in the electric iron reduction furnace is done by the heat produced by the resistance which the electric current meets with in passing through the charge between the electrodes, more electrical energy is required to produce the same amount of heat. Likewise, as stated by Crawford,⁷ the electrical conductivity of coke “is so good that much of the current passes between the electrodes in the upper part of the furnace. The smelting zone is thereby raised and the furnace runs hot on top with attendant melting of the arches (of the roof of the crucible) and cold at the bottom.

“*Second.*—The coke, because of its density and high crushing strain, does not break down like charcoal as the burden descends, hence less surfaces of carbon are exposed to be oxidized by the ore and there is a less intimate mixture of the two.⁸ Re-

⁶ *Trans. Amer. Electrochem. Soc.*, vol. xv, p. 168.

⁷ “Progress of Electric Smelting at Heroult, California,” by John Crawford, *Metallurgical and Chemical Engineer*, July, 1913, p. 386.

⁸ This intimate mixture is, of course, very necessary where the reduction is almost entirely performed by solid carbon, as is the case in the practice at Heroult, California.—THE AUTHOR.

duction of the ore takes place more slowly, the silicon in the iron is lowered, the consumption per ton increases, and the efficiency of the furnace is reduced."

Inasmuch as either charcoal or coke is the only practical reducing agent we know of at the present time,—that is, for use on a large scale,—and as it would seem, from what has just been stated, that it is impracticable to use coke, this necessarily limits the electric iron reduction furnace to the use of charcoal. If this be true (and it undoubtedly is at the present time), it is unfortunate, especially as regards the situation in Southern California and in other of our Western States, where there are quite large iron deposits of A No. 1 ore, but where coke is too expensive to permit of ordinary blast-furnace smelting, and where the use of charcoal for electric-furnace work is entirely out of the question, as there are no forests to furnish the wood necessary for its production. On the other hand, crude oil is generally more or less plentiful and comparatively cheap in such districts, especially in California. Aside from its possible use in connection with electric-furnace work, those interested in the subject have for years been considering the possibility of using crude oil as a reducing agent. So far as we are aware, this has not as yet been successfully done. That the carbon and the hydrogen of the oil will reduce iron oxides is self-evident, but as yet no one seems to have been able to solve the problem as how to bring the ore and the oil together at the proper temperature. Perhaps ultimately a suitable process may be devised whereby the oil may be used as a reducing agent, and thus broaden the field for the possible application of the electric furnace in the reduction of iron ores, for, from what has been stated above, it is apparent that the electric furnace is limited for such purposes at the present time to those localities where charcoal and electric power are comparatively cheap.

STEEL.

Turning now to the production of steel, one of the most serious problems which presents itself is the fuel problem. As is well known, there has been a gradual transition from the Bessemer to the open-hearth process, till to-day the Bessemer process seems destined to act simply as an auxiliary to the open-hearth

and electric-furnace process. As is also well known, whereas the heat in Bessemerizing is obtained by the rapid oxidation of silicon and carbon content of the metal, in the open-hearth the heat is derived from an extraneous source; that is, from the combustion of coal or of gas, and the latter may be either producer or natural gas. When coal has been used either directly or for producing gas, the sulphur content of the same has been less than 1 per cent. Nowadays, however, coals with as low a sulphur content as this are becoming scarce, as is, likewise, natural gas. When a coal, or the producer gas made from it, is used which contains a larger sulphur content, the sulphur content of the steel is appreciably increased. The problem, therefore, that presents itself is how these high-sulphur coals may be used without impairing the quality of the steel.

Use of "Powdered" Coal and Loss of Sensible Heat.

In steel making there is still room for considerable improvement along the line of heat efficiency; that is, of getting out of the fuel that is used in heating the furnace the greatest number of calories and of conserving or utilizing the heat after it has been obtained. As a means to this end, a great deal of work is at present being done, and has been done, on the use of powdered coal as a fuel. By using coal in this manner the producer can be done away with. Although the prospects for being able to use powdered coal successfully are very favorable, much work will yet have to be done before a method has been perfected, and even when solved the problem of stack losses in sensible heat, which are enormous in the open-hearth work, will still have to be dealt with. At present much effort is being directed toward saving this heat by using it under boilers, etc.

The Use of the Electric Furnace as a Solution of These Problems.

As is well known, in the electric furnace the heat is generated at the point where it is needed. Take, for example, the Heroult furnace, or any other furnace of that type. The furnace itself is nothing more than a chamber built up of refractories and encased in steel. Through the roof of the chamber pass the electrodes, two or three in number, as the case may be, and the heat is generated in the furnace at the point where these electrodes

come in contact with the charge. Thus it is plain to be seen that by using the electric furnace the two difficulties above mentioned may be avoided; that is, contamination of the steel by the impurities contained in the fuel, and the loss of heat which results in an open-hearth practice by reason of the large volume of gas that is constantly passing through the furnace and carries with it a large amount of sensible heat which is not conserved in the checker work of the regenerators. It would seem, therefore, as if the electric furnace were the solution of this problem, for not only would the difficulties above mentioned be avoided, but a better grade of steel would be produced. As a matter of fact, a better grade of steel can be produced in the electric furnace than in the open-hearth furnace. In corroboration of this statement may be cited the experiments which during the past four years have been conducted by the United States Steel Corporation.⁹ These experiments have shown that the electric-furnace process, as compared to Bessemer and open-hearth processes, has the following advantages:

- (1) The more complete removal of oxygen.
- (2) The absence of oxides caused by the additions, such as silicon, manganese, etc.
- (3) The production of electric steel ingots of 8 tons weight and smaller that are practically free from segregation.
- (4) Reduction of sulphur to 0.005 per cent. if desired.
- (5) Reduction of phosphorus to 0.005 per cent., as in the basic open-hearth process, but with the complete removal of oxygen.

Some test rails made from acid Bessemer steel refined in a basic electric furnace were comparatively soft, but have shown superior wearing qualities compared with Bessemer rails in the same tracks and under the same service conditions. The steel from which these rails were made has the following composition: Carbon, .055 per cent.; manganese, 0.137 per cent.; silicon, 0.13 per cent.; sulphur, 0.017 per cent.; and phosphorus, 0.022 per cent. It is stated that there are now about 5600 tons of standard electric steel rails which have been in service in the United States for the past two years, and that these rails have been subjected to all sorts of weather and other conditions. It is also stated that no basic electric steel rails in service in this country

⁹ *Metallurgical and Chemical Engineering*, vol. x, 1912, p. 371.

have yet broken. The results of a number of tests have shown that electric steel of a given tensile strength has a slightly greater amount of elongation than basic open-hearth steel, and is somewhat denser than basic open-hearth and acid Bessemer steel. The result of some tests made at South Chicago by the Illinois Steel Company (see Table II) shows 15.5 per cent. increased ultimate strength for electric steel and 11.3 per cent. decreased elongation (in 2-inch) as compared with open-hearth plate steel of approximately the same chemical analysis.

TABLE II.¹⁰

Statement of Averages of Ultimate Strength and Per Cent. Elongation of Electric and Open-Hearth Plate Steels.

Carbon, per cent.	Ultimate strength, lbs. sq. in.	Per cent. elongation.	Carbon, per cent.	Ultimate strength, lbs. sq. in.	Per cent. elongation.
0.08	59,194	27.25	0.08	51,690	32.00
0.12	64,080	26.05	0.12	56,510	29.70
0.16	69,220	25.25	0.16	52,901	28.61
0.20	72,853	22.82	0.20	58,294	28.82
0.24	69,540	23.12	0.24	63,560	26.25

Why is it, then, that the electric furnace is not more extensively used for steel making? It seems to be a matter of cost. In other words, where large tonnages are required, due to the comparatively high cost of electric power, steel can be more cheaply produced in the Bessemer or open-hearth furnace than in the electric furnace. For this reason, unless a better grade of steel is derived than can be produced in the Bessemer or open-hearth processes, the latter processes are used.

Cost of Production of Steel in the Electric Furnace.

This will, of course, depend upon local conditions. As a rule, the cost of power is the governing factor in electric-furnace work; but in the refining of steel this item of cost does not play such an important part as it does in some other electrometallurgical processes. For example, electric-furnace plants are being successfully operated in localities where power costs ten cents

¹⁰ *Transactions American Electro-Chemical Society*, vol. xix, 1911, p. 221.

per kilowatt-hour, but when the cost for raw material would be the same for either the open-hearth or for the electric furnace. On the other hand, a plant may be located in a remote locality where the cost of power is very low, say 0.20 cent per kilowatt-hour, but when the cost of raw materials may be comparatively high. In Tables III–VIII are given the estimated cost of producing steel at various places and in various types of furnaces.

These figures are only for conditions as prevailing at Ugine.

TABLE III.

Production Cost of Steel from Cold Scrap, Girod¹¹ Furnace, Ugine, France.

	2.5- to 3-ton furnace.		10- to 12-ton furnace.	
Raw materials:				
Scrap, 1100 kilogrammes, at \$15 per ton . .	\$16.50		\$16.50	
Slag.....	0.46		0.46	
Deoxidizing additions and recarburizing . .	0.70	\$17.66	0.70	\$17.66
Producing cost:				
Electric power, 850 and 750 kilowatt-hours, at 0.20 cent.	3.40		3.00	
Electrodes at \$64 per ton.....	0.60		0.70	
Wages.....	0.60		0.30	
Maintenance and repairs.....	2.40	7.00	1.60	5.60
Total cost per ton.....		\$24.66		\$23.26

TABLE IV.

Production Cost of Steel from Molten Charge, Girod¹¹ Furnace, Ugine, France.

	2.5- to 3-ton furnace.		10- to 12-ton furnace.	
Raw materials:				
Liquid steel, 4 per cent. loss in heating (1040 kilogrammes, at \$16 per ton)	\$16.64		\$16.64	
Slag	0.40	\$17.04	0.40	\$17.04
Producing cost:				
Electric power, 275 and 300 kilowatt-hours, at 0.2 cent.	1.10		0.80	
Electrodes at \$64 per ton.....	0.25		0.25	
Wages, 8 heats per 24 hours.....	0.20		0.20	
Maintenance and repairs.....	0.80	2.35	0.50	1.75
		\$19.39		\$18.79

¹¹ *Metallurgical and Chemical Engineering*, vol. x, 1912, p. 663.

NOTE.—The estimate of Girod does not include expense for ingots, moulds, superintendence, laboratory, amortization, general charges, or royalty charge.

TABLE V.

Refining Cost Per Ton of Steel from Molten Charge, in a 2-Ton Gronwall Furnace Operating under English Conditions, Sheffield, England.

	Without dephosphorizing.	Dephosphorizing.
Number of charges per week.....	40	30
Tons per week.....	80	60
Cost per ton of steel:		
Power at 0.5 cent per kilowatt-hour.....	200 kw.h. \$1.00	250 kw.h. \$1.25
Repair of roof.....	0.16	0.20
Dolomite (100 pounds per charge).....	0.17	0.17
Electrodes at 4 cents per pound.....	0.18	0.22
Sundry costs.....	0.14	0.16
Royalty.....	1.50	1.50
	\$3.15	\$3.50

In the above estimate the cost of labor, amortization, interest, raw materials, and general charges are omitted. The figures refer to the production of steel with sulphur and phosphorus below 0.02 per cent.

TABLE VI.

Cost of Production for a 2-Ton Three-Phase Rochling-Rodenhauser Furnace Producing Steel for Castings from Molten Metal.

	Per ton of steel.
Lining: Raw materials.....	\$0.304
Wages.....	0.043
Heating up furnace: 2000 kilowatt-hours, at 2.17 cents for 160 tons.	0.272
Refining: 300 kilowatt-hours per ton, at 2.17 cents.....	6.52
Wages.....	0.425
Materials: 20 kilogrammes mill scale.....	0.082
30 kilogrammes lime.....	0.087
6.5 kilogrammes ferrosilicon.....	0.485
4.0 kilogrammes ferromanganese.....	0.214
Power for cooling arrangements.....	0.196
Repairs.....	0.194
	\$2.822

To the above must be added interest and depreciation of the plant. Taking 5 per cent. interest and 10 per cent. depreciation on \$13,380, which will be the approximate cost of the plant, gives \$2000 per year, which for 300 working days would give 41.2 cents per ton, so that the conversion of the fluid product from the basic converter into high-grade steel suitable to replacing crucible steel for steel castings will cost \$9.23 per ton, exclusive of cost of molten steel charged: this on a basis of three men operating the furnace.

TABLE VII.

Cost of Producing Rail Steel in a 7-Ton Three-Phase Rochling-Rodenhauser Furnace from Fluid Steel.

	Per ton.
Raw materials, steel at \$15.54 and all fluxes.....	\$16.56
Power at 0.58 cent per kilowatt-hour: Heating up.....	0.02
Refining.....	0.72
Wages: On furnace.....	0.16
On lining.....	0.008
Lining materials.....	0.072
Tools.....	0.097
Repairs.....	0.194
Amortization and interest.....	0.168
Licenses.....	0.582
	<hr/> \$18.62

This estimate includes all items and, aside from the cost of molten steel, gives \$3.08 per ton as the refining cost with power at 0.58 cent per kilowatt-hour.

TABLE VIII.

Cost of Producing Steel in the Rochling-Rodenhauser Furnace from Cold Scrap, at Lansdowne, Pa.

Raw material (scrap).....	\$14.50	
Oxidation loss about 2 per cent.....	.29	
	<hr/> \$14.79	\$14.79
Current, 844 kilowatt-hours, at 0.7 cent.....	5.91	
Fluxes.....	.76	
Ore.....	.05	
Labor.....	1.50	
Tools, repairs and bottom.....	.76	
Cooling air for transformers.....	.12	
	<hr/> 9.10	9.10
Conversion cost.....		1.50
Interest, 5 per cent.; depreciation, 10 per cent. per ton.....		<hr/> 1.50
Cost of one gross ton (2240 pounds) electric steel ready to pour		\$25.39

Thus we see that under present conditions the electric steel furnace cannot compete, so far as costs are concerned, with the Bessemer or open-hearth processes. However, there is now a tendency among consumers of steel in larger amounts for rail and structural purposes to require a higher grade steel at an increased cost rather than a steel of the grade of the acid Bessemer, or even of basic open-hearth steel at a lower price.

The Field for the Electric Furnace.

It is probably in combination with either the acid Bessemer or the basic open-hearth processes that the electric furnace seems destined to occupy a prominent position in the manufacture of tonnage steel. The cost of super-refining the molten steel from either of these processes in the electric furnace, exclusive of cost of molten steel, varies from \$1.50 to \$2.25 per ton, depending on the cost of power and the impurities to be removed.

Piping in the Ingot.

One of the problems which has confronted the steel makers from the very beginning has been that of the ever-present pipe in the ingot, and it is still a problem. Various remedies for this difficulty have been proposed from time to time, such as keeping the ingot open by means of a hot top so that the top does not solidify before the remainder of the ingot has had a chance to do so. Others have proposed fluid compression, but it has never developed into general application. Recently Talbot has come forward with a method, which had been proposed some years ago, of producing a sound ingot by lateral compression of the ingot while its centre is still liquid.

Talbot states ¹² that his investigation of the subject has extended over several years, that his results and conclusions are based upon an investigation of more than one hundred large ingots, and that he has no hesitation in saying that any one following with ordinary care the method he has outlined will be able to obtain similar results on ingots of approximately the same size. Be that as it may, most steel metallurgists feel that none of the methods proposed exactly meets the requirements, and that heavy cropping is the surest and safest remedy where the pipe seriously affects the products.

¹² B. Talbot, "The Production of Sound Steel by Lateral Compression of the Ingot," *The Journal of the Iron and Steel Institute*, vol. 87, p. 30.

THE DIRECT REDUCTION OF IRON ORES.

The term "direct process" in relation to iron smelting has been used with two distinct meanings. It has been applied to the methods of making wrought iron and steel without overcarbonizing the product at any stage in the process, to distinguish such a process from the usual procedure of first making pig iron in the blast furnace and subsequently decarburizing and refining it. The phrase "direct process" has been applied also to methods of smelting iron in distinction to the blast-furnace practice of burning a great part or all of the carbon to carbon monoxide at the tuyères, thereby proportionally lessening the power possessed by the carbon of abstracting oxygen from the ore. In this latter sense, therefore, the distinguishing feature of a direct reduction process is that, by dispensing with the blast, the oxidizing of any of the reducing material by any other agent than the oxygen of the ore is avoided.

Using the term with this meaning, the simplest "direct reduction" method is obviously to place ore and coal (or other reducing substance) in a closed vessel and apply heat externally. At the proper temperature, as is well known, the carbon will take the oxygen from the ore and release the metal. The hitherto insurmountable difficulty in applying the seemingly very simple principle on an industrial scale to iron ore reduction has been on the score of heat economy. The advantages which such a process offers have attracted iron manufacturers for generations, and to-day, with the advent of the electric furnace, the hope and effort of metallurgists are again turned to the solution of this problem, and with much brighter prospects of success than have cheered the experimenters of the past.

The advantages of a practicable direct process are many. The blast furnace as it is at present constructed and operated is clearly restricted to the use of charcoal, coke, and anthracite. Its product, if used for steel making, contains carbon much in excess of the quantity needed. This excess carbon represents a waste of fuel and needlessly lengthens the refining operation. The nitrogen of the blast, by diluting the reducing gases of the blast furnace and by increasing their volume and consequently their velocity, does not permit them to remain in contact with the ore a sufficient length of time to exercise fully their reducing power.

A direct reduction process, on the other hand, holds forth the promise of utilizing fuel and reducing material of most diverse character, such as soft and non-coking coals, peat, oil, natural gas, etc. In many localities there are extensive deposits of readily minable ore of good quality, which are unavailable, because fuel suitable for blast-furnace operation can be obtained only at prohibitive cost. In new countries, where small quantities of material are required, a direct process capable of operation in much smaller units than a blast-furnace installation would be invaluable.

The possibility of reducing iron directly from its ore, and even of reducing and refining the metal in a single operation, is not questioned. That such procedure is more rational than the present general method of making an impure pig iron and subjecting it to a refining process to convert it into steel is questioned only in its economic aspects. Neglecting, for the present, electrical methods, direct processes have hitherto proceeded along one of two lines. The oldest method, typified by the native or Catalan forge, is to heat the mixture of ore and fuel in an open hearth. The second method is to heat the mixture of ore and fuel in a closed vessel from without.

As previously stated, there is abundant evidence that wrought iron and steel were in use in many parts of the world many centuries before the Christian era, and there is little doubt but that they were made by such simple and direct processes as are still used by natives in parts of India, Bermuda, and Africa.

Modified types of this old process have come down to us even to the present day. In this country it was the American bloomery. The yield of metal from such a furnace was relatively small and the cost of labor and fuel and the loss of iron in the slag relatively high. Coke can not be used as a fuel except in a few special cases, because the spongy iron produced at the low temperature readily absorbs sulphur from the charge. So far as the writer is aware, there have been no bloomeries in operation in this country since 1901.

Turning now to the second method, namely, the heating of the mixture of the ore and fuel together, the following are some of those processes that have been devised in the past for the purpose of producing iron and steel directly in this manner.

One of the earliest of the gas-fired open-hearth furnaces for

direct reduction was introduced by Sir W. Siemens in 1873.¹³ A mixture of fine ore and coal was treated in a rotating cylindrical furnace heated internally by producer gas. A very basic and fluid slag was obtained with the almost complete removal of phosphorus and sulphur. The resulting metal was balled and squeezed and used either in the open-hearth steel furnace or for working into wrought iron. The deoxidation of the ore was successful, but the reoxidation of the sponge and loss of iron in the slag were fatal to the process.

Many modifications of the reverberatory hearth have been tried. In the Renton Process (1851) a mixture of fine ore and coal or charcoal in vertical retorts erected at the end of a puddling furnace was heated by the waste gases and partially reduced before it was dropped to the puddling hearth. Wilson's process,¹⁴ which was tried in this country in the '80's and proved commercially unsuccessful, did not differ essentially from Renton's process. Several furnaces combined a reverberatory furnace and a shaft. Into the latter the ore mixture was charged and heated by direct contact with the hearth gases with the object of further utilizing the reducing power of the gases and obtaining preliminary partial reduction.

The Eames process,¹⁵ as tried by The Carbon Iron Company of Pittsburgh, consisted in reducing very fine ore mixed with coke or "graphite anthracite" on the bed of a reverberatory furnace fired with natural gas. The charge consisted of about one ton of rich ore and 500 pounds of anthracite or coke ground to pass a 16-mesh sieve and mixed with a little lime and enough water to make it plastic. This was spread as a layer about 4 inches thick on the coke- or anthracite-lined floor of the furnace and the ore reduced at a low heat. The object in using lime-washed coke in place of charcoal was to retard the combustion of the carbon and so give time for the oxygen of the ore to combine with

¹³ *Journ. Iron and Steel Institute*, 1873, i, p. 37; 1877, ii, p. 345. *Trans. Amer. Inst. Min. Engrs.*, viii, p. 321.

¹⁴ *Trans. Amer. Inst. Min. Engrs.*, 1884, xii, p. 522. "Adams's Process," *Journ. Iron and Steel Inst.* (Amer. vol.), p. 317. H. M. Howe, "Metallurgy of Steel, p. 270; I. Sterry-Hunt, "Geological Survey of Canada," Rept. Progress, 1886-9, p. 274.

¹⁵ *Journ. Iron and Steel Inst.*, 1888, vol. ii, p. 252; 1889, vol. ii, p. 423. *Trans. Amer. Inst. Min. Engrs.*, vol. xvii, pp. 668-679.

the coke. The spongy iron obtained was used in the open-hearth and crucible processes.

Chenot's process (1851)¹⁶ consisted in reducing the ore in externally heated retorts by either charcoal or carbon monoxide from a gas producer. The sponge was worked into a bloom in a charcoal hearth or melted in crucibles.

In Blair's process,¹⁷ a modification of Chenot's introduced in 1870, very hot producer gas was passed through a mixture of ore and charcoal in retorts.

The chief weakness of both the Blair and Chenot process was the difficulty of economically heating the retorts and the smallness of the output.

A recent process and one which recalls the work of Siemens is the Jones¹⁸ process, experimental work on which has been done at Iron Mountain, Mich.

These various direct processes, although industrial failures, have demonstrated that it is possible to make iron of considerable chemical purity from phosphoric ore, and, when pure magnetites are used, an iron of exceptional quality, suitable for tool steel and similar purposes.

The Application of the Electric Furnace to the Direct Reduction of Iron Ores.

In the second method of direct reduction which we have discussed,—namely, the mixing of the ore with the reducing agent and then heating it,—two prerequisites have to be met,—namely, to maintain a sufficiently high temperature to effect reduction, and to maintain a reducing atmosphere. As just stated, none of the processes devised have been able to do this in a commercially successful manner. In the electric furnace, however, it is not difficult to meet either of these prerequisites. If, for example, we place a mixture of ore and carbon in the crucible of an electric furnace of the Siemens or Heroult type, heat is generated by the resistance which is offered to the passage of the current

¹⁶ Percy Iron and Steel, pp. 335-345; Brit. Pat. 1590, A.D. 1856.

¹⁷ *Journ. Iron and Steel Inst.*, 1878, vol. i, p. 47; *Iron Age*, 42, p. 119; U. S. Pat. 126,922, May 21, 1872.

¹⁸ John T. Jones, Patents: 1908—880,799, 890,229, 890,230, 890,231, 890,232, 890,233, 890,234, 890,235, 891,549, 891,704, 891,705, 899,405. 1909—12,928. 1911—981,280.

through the charge, and the heat may be increased or decreased by the amount of current passed. As it is not necessary to admit air to the furnace, the atmosphere may be kept strictly reducing. If the carbon be carefully controlled,—that is, enough carbon is provided for the reduction of the iron of the ore, but not enough to reduce other metals that may be present or to combine with the reduced iron,—a malleable iron or steel may be produced. Although many experimenters¹⁹ have worked on this subject, and although the field appears to be a promising one, it yet remains for some one to demonstrate the feasibility of such a process in a commercial scale.

Problems in Non-Ferrous Metallurgy.

Turning our attention to non-ferrous metallurgy, let us briefly consider one or two of the problems that are now confronting the workers in that line of metallurgical work.

Concentration Problems.

As is well known, in the metallurgical treatment of many ores it is first necessary to give them a preliminary concentration treatment in order to raise the metallic content of the ore to a sufficiently high percentage to permit of its being successfully treated commercially. In other words, the object is to separate the valuable part of the ore from the worthless gangue material. In doing this it is often difficult, due to the nature of the ore, to obtain a clean separation. This is especially true in the treatment of ores when the specific gravity of the gangue material and of the mineral to be saved closely approach each other,

¹⁹ Experiments of Stassand, "Electrochemical and Metallurgical Industry," vol. vi (1808), p. 315; *Ibid.* (1906), pp. 125, 152, 265, 332. "Metallurgical and Chemical Engineering," vol. ix (1811), p. 642.

Investigations of J. W. Evans, *Journal of the Canadian Mining Institute*, vol. ix, p. 128; *Ibid.*, vol. xiii, p. 151.

Experiments of "La Neo Metallurgie," *Revue de Metallurgie*, Dec., 1910, p. 1190.

"The Application of the Lash Process to the Electric Furnace," *Trans. American Electrochemical Society*, vol. xiv (1908), p. 239; vol. xv, p. 149.

Research work of R. M. Keeney on "The Production of Steels and Ferro-Alloys Directly from Ore in the Electric Furnace," Carnegie Scholarship Memoirs, Iron and Steel Institute (England), vol. iv (1912), p. 108.

for the majority of concentration methods are based upon the separation of minerals, generally in water, by reason of the difference in their specific gravities. Difficulties are generally encountered when attempting to treat ores which have to be very finely ground in order to free the metallic minerals from the gangue minerals, or when a portion of the metallic minerals may be in the form of carbonates. Due to causes of this kind, it may not be possible to save by concentration more than 55 to 65 per cent. of the metallic mineral contents of the ore. Thus we see that if true progress in metallurgical practice means conservation, there is a big field for improvement in the treatment of those ores which of necessity must be concentrated before they can be economically treated by present-day metallurgical processes. In other words, the problem resolves itself into devising more efficient methods of concentration, or else of devising processes which can economically treat the ore without its having to be concentrated.

The Treatment of Complex Ores.

As was only natural, in the winning of metals from their ores, especially in this country, those ores were treated which would most easily give up their metals. Take, for example, gold: It was first obtained from the river beds by panning, by cradling, and by sluicing. The river deposits becoming worked out, the miners began to prospect. They discovered the gold-bearing minerals in place. The gold was in the native state, and all they had to do was to crush the ore and amalgamate the gold. Gradually the nature of the ore changed, and soon parts of it contained gold values which could not be extracted by amalgamation. This meant that concentration had to be resorted to in order to save these valuable gold-bearing particles from the tailings of the stamp battery. Then processes had to be devised for treating the concentrates. As time went on it became necessary for metallurgists to turn their attention to the treatment of ores more and more refractory and complex, until at the present time the metallurgical profession is confronted with the problem of successfully treating such ores. In a complex ore the metallic minerals (sulphides) which generally predominate are those of zinc, iron, copper, and lead, and it is generally zinc which gives the trouble. As pointed out by Dr. Parsons in Bul-

letin No. 47 of the Bureau of Mines, "besides the losses in mining and concentration of zinc ores, there are incalculable losses, which, without question, run into millions of dollars, and undoubtedly exceed the total value of the zinc mined, in slags and waste products, from other processes. Zinc has been and generally still is considered about the worst impurity to be found in the ores of copper and lead, for it has always given trouble in their metallurgy. Accordingly, the practice has been so to run the charge that the zinc passes off in the slag, and to a certain extent in the flue dust. The economical treatment of some ores has been impossible on account of the high percentages of zinc they contained. . . . To make even an approximate estimate of the total loss of zinc is impossible, but it certainly exceeds thousands of tons daily."

Much attention is being given to this subject. Perhaps none of the processes which have been proposed will be the final solution of the problem, but rather that some one process will be found to be applicable under certain conditions, while under other conditions some other process will best meet the requirements. For the sake of convenience, we may classify the methods which have been proposed under the following headings:

- (1) Special smelting processes.
- (2) Chemical processes.
- (3) Electric-furnace processes.

In this connection, we will not attempt to do more than to briefly consider the electric furnace method of zinc smelting.

PRESENT METHODS OF ZINC SMELTING.

Briefly outlined, the process is as follows: The ore is roasted, for the purpose of converting the zinc into zinc oxide. It is then mixed with the proper amount of reducing agent and placed in a closed fire-clay retort, to which is attached a condenser. The retort is kept at a temperature of from 1100° to 1300° C. The zinc oxide is reduced to zinc at a temperature of 1033° C. As the boiling point of zinc is somewhere between 920° and 930° C., the reduced zinc is at once vaporized, and then subsequently condensed as a liquid metal in the condenser, within the temperature range of 860° C. down to 420° C., the higher temperature being that at which metallic zinc approaches the vaporization point, while the lower temperature is that of the solidifica-

tion of zinc. In order to successfully carry out the process as above outlined, the temperature and the vapor must be carefully controlled, for if the temperature gets too low, or the vapor too dilute with carbon dioxide instead of carbon monoxide, or with metallic vapors other than zinc, what is known as blue powder is formed, which consists of minute particles of zinc, each one apparently covered by a thin coating of zinc oxide. If formed, this blue powder is a source of a great deal of trouble, as it cannot be converted to spelter by a single melting.

As a retort holds only about 200 pounds of mixture, the process is necessarily an intermittent one. After a charge has been smelted, the zinc is removed from the condenser, the residue is raked out of the retort, and the latter is then ready for another charge. Due to the process being an intermittent one, the labor cost is comparatively high, and, as the heat has to be conducted to the charge through the walls of the retort, the thermal efficiency of the process is low.

The Use of the Electric Furnace in Zinc Smelting.

Due to the drawbacks of the present method of zinc smelting, as above mentioned, various attempts have been made to obviate them by the use of the electric furnace. In fact, more progress has been made to date in the electric smelting of zinc ores than with the electric smelting of any of the non-ferrous metals, except aluminum and metals which are used in the production of ferro-alloys. The processes which are used in the electric smelting of zinc ores are of two general classes. The first of them is based upon the reduction of zinc oxide and its compounds by carbon and carbon monoxide; the second, upon the decomposition of zinc sulphide by metallic iron.

Reduction by Carbon and Carbon Monoxide.

Considering, now, the first of these processes,—namely, the reduction of zinc oxide and its compounds by carbon and carbon monoxide,—the one essential difference between reduction in a retort and in an electric furnace in this manner is that in a retort the process is intermittent, whereas in the electric process it may be continuous. If continuous, the furnace is charged at intervals, as may be necessary, and the metal is recovered from the condenser just as in the retort process.

On the other hand, as above stated, the slag in the retort process is raked out of the retort, as it is never fluid enough to be tapped out, whereas in the electric furnace it is tapped out at intervals, or is allowed to run from the furnace continuously. In either case the continuous operation of the furnace is not disturbed.

Although in an electric-furnace process of this kind the reduction of the zinc oxide by carbon or carbon monoxide occurs just as in the retort process, the reduction seems to take place much more rapidly in the electric furnace, as designed at the present time, and the reaction $\text{CO}_2 + \text{C} = 2\text{CO}$ does not seem to take place as well in the electric furnace as in the retort. On this account the atmosphere of the electric furnace contains a larger per cent. of carbon dioxide than does the atmosphere of the retort, and as a result a larger amount of blue powder is formed in the electric furnace during the condensation of the vapors than is formed in the retort.

The Use of Iron as a Desulphurizing Agent in Electric Zinc Smelting.

There are at least two electric furnace processes²⁰ for the smelting of zinc ores which are based upon the use of iron as a desulphurizing agent. However, they do not seem to have advanced as far as reduction of the oxide with carbon. The same trouble is experienced in the use of iron as a desulphurization agent as when carbon is used as a reducing agent,—namely, in condensation a large amount of blue powder is formed which has to be resmelted. This is probably due to the volatilization of iron and iron sulphide, which, together with the other vapors

²⁰ These processes are the Imbert and Cote-Pierron processes. "Imbert tried out the reaction without much success in the combustion furnace. Thompson and FitzGerald later designed an electric furnace for its application. Although the Imbert-Thompson-FitzGerald process has been tried experimentally on apparently a good-sized scale for two years in Upper Silesia, little authoritative information has been given out concerning it. Several types of resistance furnace have been used, all having a resistor of solid carbon."

"The Cote-Pierron process is performed in a furnace of the Siemens type, or one having two vertical electrodes in series, both types being roofed and connected with a column of electrically-heated carbon, through which the vapor passes before going to the condensing chamber."

that are given off, dilute the zinc vapor and so bring about the formation of blue powder in condensation, as is the case when zinc oxide is reduced with carbon.

The Problem to be Solved in Connection with the Electric Furnace Smelting of Zinc Ores.

From what has just been stated, it is evident that the problem in connection with the use of the electric furnace in the smelting of zinc ores lies in devising a furnace which may be operated in such a manner as will prevent the formation of blue powder instead of metal, under the peculiar conditions of the electric furnace. The problem is, therefore, not an electrical or mechanical problem, but a metallurgical problem, and its solution, as before stated, lies in devising a furnace in which the metallurgical difficulty now met with may be successfully overcome,—namely, the presence in the vapors of the furnace of an excessive amount of carbon dioxide, with the consequent formation of blue powder.

It must not be inferred from what has been stated that the electric furnace is not being used commercially for the smelting of zinc ores. As a matter of fact, it is, but, so far as the writer is aware, only in Sweden and Norway, where some 8000 to 10,000 electric horsepower is used for that purpose. Not much has been published as regards the work which has been done in these countries, except a report by F. W. Harlord,²¹ published in 1911, in which he states that the weak point of the process is the large amount of metallic powder produced in proportion to the metals, as two tons of blue powder were being smelted at Trollhättan, Sweden, for each ton of ore treated.

THE SMELTER FUME PROBLEM.

The ores which are smelted in non-ferrous metallurgical work are largely of the sulphide class. Such ores may either be given a preliminary roast and then smelted, or they may be smelted directly in the blast furnace. In either case obnoxious fumes are given off,—that is, certain portions of the charge may be volatilized either in the form of metals, oxides, sulphides, sulphates, or chlorides of metal. Sulphur is converted for the most part into

²¹ *Engineering and Mining Journal*, Feb. 10, 1912, p. 344.

sulphur dioxide, and, under certain conditions favorable to the same, the sulphur dioxide is further oxidized to sulphur trioxide (SO_3). All of these products,—that is, the fine particles of ore, the volatilized products, and the sulphur gases,—pass off with the furnace gases. By means of mechanical devices, such as bag houses, or by means of the Cottrell Process,²² the solid particles can be removed from the furnace gases, but so far no mechanical device has been designed which will handle the sulphur gases, which, if present in appreciable amounts, are very destructive of the vegetation which may be found in the region adjacent to the smelting plant. An idea of the large volume of these gases may be gained from the fact that in smelting 1000 tons of pyrite ore, approximately 800 tons of sulphur and oxygen are discharged into the atmosphere. About the only method which has proved commercially effective, so far, for the removal of sulphur trioxide from furnace gases has been the absorption by water, and this is not commercially feasible, unless it is desired to manufacture sulphuric acid; and, again, it is not commercially feasible to manufacture sulphuric acid unless the smelting works are located in some section of the country from which the acid may be easily marketed. In other words, although it may be feasible to convert sulphur gases into sulphuric acid at Ducktown,²³ Tenn., it is not feasible to attempt to do so at Great Falls or Anaconda, Mont., as there is a comparatively limited demand for sulphuric acid in that part of the country at the present time. The problem, therefore, for such districts as Great Falls and Anaconda resolves itself into one of recovering the sulphur from the smelting operation in the form of elemental sulphur or as some by-product, as is done by the Sprague²⁴ process, in which process the sulphuric acid is neutralized by zinc oxide, lime, or magnesia, and the fume removed by filtration through

²² F. G. Cottrell, "Electrical Fume Precipitation," *Trans. Amer. Inst. Ming. Engrs.*, Feb., 1912.

Linn, Bradley, "The Electrical Precipitation of Suspended Particles by the Cottrell Process," *Journal of Industrial and Engineering Chemistry*, vol. iv, No. 12, Dec., 1912.

²³ Freeland, W. H., and Renwick, C. W., "Smelting Smoke as a Source of Sulphurous Acid," *Eng. and Min. Journ.*, May 28, 1910, p. 1116.

²⁴ C. B. Sprague, "Sprague Process for Treating Furnace Gases," *Eng. and Ming. Journ.*, Mar. 5, 1910, p. 519.

fabrics. A great deal of thought has been given to this subject, and a great deal of experimenting done. At the present time there are two processes which are now being watched by the non-ferrous metallurgical world with interest. The first of these is the Thiogen²⁵ process, which is based upon the fact that by uniting sulphur fume with carbon and then passing the product over limestone containing iron salts the gas is decomposed and sulphur precipitated. In the Thiogen system an oil spray is used to supply the carbon, while calcium sulphide is used as an accelerating agent.

The second and most recent process is that of Hall, who proposes to remove the sulphur from the ore direct by distillation, and to thus prevent the formation of oxidized sulphur gases which must be subsequently reduced or neutralized. In order to obtain the sulphur in the manner above indicated, the ore is roasted at a temperature between 700° and 900° C. in a neutral or non-reducing atmosphere, a certain amount of water as steam is introduced into the furnace during the roasting operation. The base metals are thus oxidized and the sulphur is distilled without becoming oxidized, and is collected in a gas washer or by some other suitable means.

HYDRO-METALLURGY OF COPPER.

In closing, perhaps I can do no better than to cite the hydro-metallurgy of copper as one of the great problems which now confront the non-ferrous metallurgist. As stated in the *Engineering and Mining Journal*, in a recent editorial on this subject, it is perhaps the greatest. While it is only recently that this subject has attracted very much attention in this country, it is by no means a recent innovation, as hydro-metallurgical methods of copper extraction have been used in Portugal and Spain for a long time, being particularly suited to the peculiar conditions to be found there, but they have never been employed to any large extent in this country. In general the process consists of getting the copper values into a soluble form, if they are not already in that condition. Sulphuric acid is generally used as a leaching agent. The copper may then be precipitated out of solution by

²⁵ "The Thiogen System of Fume Control," *Metallurgical and Chem. Engineering*, vol. x, 1912, p. 710.

any one of three methods,—namely, by iron, by hydrogen sulphide, or electrolytically. There is still a difference of opinion as to which of these methods is preferable. There is still much work to be done on this problem, but it is not believed that the difficulties are insurmountable, and, moreover, it is confidently believed that the process will be developed along modern lines and in accordance with modern practice, until the hydro-metallurgy of copper shall have reached a stage of development comparable to that of the hydro-metallurgy of gold and silver ores, as exemplified in the cyanide process. In other words, it is confidently predicted by those who are familiar with the work that we are to have a new metallurgy of copper. As can be readily understood, the hydro-metallurgy of copper is one solution of the fume problem, mention of which has previously been made.

There are doubtless many other metallurgical problems to be solved, mention of which could be made by those present, but it is believed that those named will suffice to give some idea of the nature and extent of the problems with which the metallurgist is confronted at the present time.

In closing, the writer wishes to express his thanks to his colleagues, Messrs. R. M. Keeney and J. F. Cullen, for data furnished in preparing this paper.

PITTSBURGH, PA., December, 1913.

Société Française de Photographie. The French Society of Photography at Paris announces a photographic exhibition to be held in the spring of 1914. The exhibition is open to all photographers, amateur and professional, members and non-members of the society. Material for exhibits should be sent to 51, Rue de Clichy, Paris (9^e), France, before the 15th of April, 1914. The exhibitors must present the results of their own labor only and subjects which have not formerly been exhibited. The exhibition will be divided into five sections:

1. Prints intended to be framed under glass.
2. Lantern slides.
3. Stereogrammes of all kinds.
4. Scientific subjects.
5. Reproductions by various photographic processes in black and in colors.

Exhibitors may show only a limited number of pictures in each section. Medals of silver and bronze will be awarded. A special medal in each class will be reserved for work executed in the studio of the society.

Further information may be obtained by addressing the society as above.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

MICROMETER MICROSCOPES.

AFTER pointing out numerous sources of error generally overlooked when attempting to make accurate length measurements with micrometer microscopes, the author describes a simple and rapid method of applying the proper corrections. He then explains an accurate means of measuring screw errors and a graphical procedure for computing convenient correction tables.

The advisability of carefully examining any instrument intended for accurate work is made clear by a table giving the magnitudes of the periodic errors found in some microscopes. In this connection it is pointed out that, even with such micrometers as those of the International Bureau of Weights and Measures, an error of about 1.5 can be made in comparing two lengths if the only corrections applied are those for deviations of the mean screw-values from the nominal value of 100 per revolution; and, further, that most of the error will be due to neglecting the *periodic* corrections.

After a pair of comparator microscopes have been calibrated once for all, the necessary corrections may be fully taken into account with an expenditure of labor even less than that required in the common but inaccurate practice of multiplying the changes in each micrometer reading by the mean scale-value and subtracting. The method of doing this is essentially a simplification of the procedure followed by the International Bureau in measuring the national prototype meters. The principal gain is effected by reducing to two tables (both of which can be mounted on a single card) all the information contained in the six tables used by the Bureau. Another gain is effected by recording observations in such a form that the corrections can be added directly without any copying of figures. The advantages of the method are illustrated by examples of actual measurements.

The calibration of a microscope by one of the processes usu-

* Communicated by the Bureau.

ally described involves such laborious calculations and least-square adjustments that it is no wonder to find it attempted only as a last resort when the demands of high accuracy compel. While, of course, the complete calibration of any divided scale requires considerable time, it is, however, possible to determine microscope corrections more accurately and with less labor than would appear from previous accounts. The whole procedure is made one of direct measurement and simple graphical addition, which is illustrated by a concrete example. The displacements of the spider-lines that correspond to certain calibration intervals are measured with an auxiliary micrometer microscope. In this way far greater accuracy is secured than is possible in the customary method of using the ocular of the micrometer under investigation. From these measurements are plotted curves which show how the intervals vary in length throughout the course of the screw. After these are adjusted so as to be mutually consistent, they are combined to form a new series from which the corrections due to screw irregularities may be read off immediately. The magnification of the microscope is then adjusted, and determined by measuring a known length. This fixes the slope of a straight base line which corrects for deviations of the nominal from the actual scale-value. A translating scale is now used for the final step of reading off the corrections to be entered in the table.

ABSTRACT OF BUREAU OF STANDARDS TECHNOLOGIC PAPER ENTITLED,

"SOME LEADLESS FRITTED GLAZES."

By E. T. Montgomery,

Assistant Ceramic Chemist.

IN the manufacture of American whiteware, china, and porcelain, and of English bone-china, a glaze composed of borosilicates of the alkalis, lime, lead, and alumina maturing at a relatively low temperature (about Seger cone 3, approximately 1100° C.) is applied to a body previously fired to the desired maturing point for the given body, approaching vitrification more or less closely. It is essential in this process that the maturing point of the glaze be considerably below that of the vitrification temperature of the body in order to avoid, in the glost fire, undue softening of the body and consequent deformation and loss. To

accomplish this purpose and at the same time to secure their inherent qualities of long temperature range, brilliancy and low viscosity, such low fusing glazes as borosilicates containing lead oxide are employed.

Chiefly on account of the poisonous nature of the lead compounds used in making these glazes, the subject of leadless glazes has aroused the interest and has received the serious attention of both technical ceramists and of manufacturers for many years. The present work was undertaken for the purpose of investigating the merits of the various types of leadless glazes thus far reported, of studying their properties and possibilities, of improving them if possible, and of making a general comparison, from a technical standpoint, between lead and leadless glazes for white-ware and china at a glaze heat of Seger cone 3 (approximately 1100°C.).

To this end numerous series of glazes were made up, being so planned as to include a number of previously-reported leadless glazes of merit, and all methodically arranged in such a way as to fully cover the range of composition which it was believed desirable to study. All of the glazes were tested over six standard underglaze colors of known composition, and all of their properties were studied in direct comparison with a standard whiteware or china glaze made with lead, half of each trial being dipped in this standard lead glaze and half in the leadless test glaze.

The results of this investigation developed many interesting technical points both in regard to leadless glazes in themselves and in comparison with lead glazes. In this brief abstract space will not admit of giving these detailed results. In general, we may say that, while lacking some of the valuable characteristics and qualities of lead glazes, leadless glazes have a few distinct advantages of their own. On the other hand, it is the writer's opinion that it would be premature at the present time to say that we can make a leadless glaze for whiteware, china, or porcelain which could be substituted for the present lead glaze. Both have special faults and special virtues, but for use under general factory conditions, make it as perfect as we can, we are not likely to find any element, compound, or combination of compounds which will exactly duplicate the many excellent properties of lead as a glaze ingredient.

THE PENTANE LAMP AS A WORKING STANDARD.

By E. C. Crittenden and A. H. Taylor.

[To be published in the *Bulletin of the Bureau of Standards* and in the *Transactions of the Illuminating Engineering Society*.]

THE best standards of candle-power are electric incandescent lamps, but it is not always practicable to use them. Of the various flame standards, the Harcourt 10-candle pentane lamp appears to be the best for general use. This lamp has the disadvantages of being large and not easily portable, of using fuel which is expensive and somewhat dangerous, and of requiring more air than ordinary ventilation will supply, but in spite of these faults its use is increasing rather rapidly.

The candle-power is not usually exactly ten, and the exact value must be determined by a photometric test. The intensity is affected by atmospheric conditions, but when the proper corrections are made a given lamp will repeat its value very closely.

It is found that the pentane commercially obtainable increases in density rather rapidly by the fractional distillation which occurs in the lamp. The density (at 15° C.) should be between 0.6235 and 0.626, but it usually reaches 0.635 when a little over half of the liquid has been used. Beyond this point there is a marked increase in the intensity of the flame. For an approximate correction, the variation may be assumed to be linear and to be one per cent. in candle-power for each 0.01 in the density of the liquid.

When the lamps are operated in a well-ventilated room, the most important cause of variation is the humidity. Water vapor in the air lowers the intensity of the flame, and variations due to that cause may exceed 15 per cent. Previous work at the Bureau of Standards * has indicated that one per cent. of water vapor in the air causes a decrease of 5.67 per cent. in the candle-power of the flame, whereas the correction officially established in England is 6.6 per cent. The present paper gives further data based on about 75,000 individual photometer settings on 27 lamps, including all lamps tested in 1911 and 1912 whose tests have extended over a range of 0.5 per cent. or more of water

* Rosa and Crittenden, *Transactions Illuminating Engineering Society*, 5, 1910, p. 753.

vapor in the air. The mean result is an exact check of the correction factor previously found at the Bureau.

To facilitate the reduction of observations to normal candle-power, a chart is given from which the departure of a lamp from normal value can be read directly when the barometric pressure and the readings of the wet and dry bulb thermometers of a ventilated hygrometer are known. The chart is plotted for a pentane lamp, but it may be applied to other flames without introducing serious errors.

TECHNOLOGIC PAPER NO. 15.

SURFACE INSULATION OF PIPES AS A MEANS OF PREVENTING DAMAGE BY ELECTROLYSIS.

By Burton McCollum and O. S. Peters.

AN investigation of the subject of surface insulation of pipes as a means of preventing damage to underground metallic structures by stray currents from electric railways has recently been completed at the Bureau of Standards. Tests were made of the various substances available for the purpose of insulation of underground structures, including paints, pitch and asphalt dips, pitch and paper and asphalt and felt wrappings, and so forth. Test specimens were made by lining shallow sheet-iron cones with the material to be tested. Before being subjected to the final test each cone was filled nearly full of ten per cent. salt (NaCl) solution and an alternating difference of potential of 80 volts (effective) applied across the coating for 30 seconds, in order to be sure that it was continuous and without flaws. A milliammeter in series with the specimen indicated a defective coating by a kick of the needle. The electrical resistances of the perfect specimens were then approximately determined with a Wheatstone bridge. In the case of the paints these resistances were found to be of the orders of from 10^5 to 10^{11} ohms per square centimetre, while for the wrappings they were much higher.

The final test of the specimens which survived the preliminary test consisted in allowing water and air alternately to come in contact with the coating while a direct potential difference of either four or fifteen volts was applied across the coating. The

value of the voltage applied depended on the thickness and other characteristics of the coating. In some of the specimens made up from each material the iron of the cone was made negative and in others positive, while in the case of the paints some of the specimens were subjected to the alternate action of air and water with no potential difference applied, in order to check up the effect of the electric stress.

The alternating contact with the coating of air and water was obtained by filling the cone and allowing the water to evaporate, which took about a week. Readings of the current flow were made at suitable intervals. The first appearance of current flow was taken as indicating the end of the useful life of the specimen as an insulating coating.

The average life of the paints was about 116 days, the maximum life obtained from any specimen being but little more than a year. No conclusive evidence was obtained that the low potential differences applied had any effect in hastening the initial failure of the coatings. The wrappings lasted longer than the paints and dips, but none of them much more than 400 days. It seems from the results that the failure of the coatings must be caused by absorption by them of water, which in time penetrates to the iron, allowing current to flow and destroy the coating by electrolysis. After the first appearance of current flow the destruction of the coating was observed to proceed very rapidly.

The conclusion drawn from the results of the laboratory tests,—*i.e.*, that the protection against electrolysis which is obtained by wrapping or painting pipes or other metallic bodies for use underground is only temporary,—is borne out by tests on insulated pipes buried in the ground under practical conditions, and also by correspondence with gas and water companies whose experiences lead to the same conclusion.

Protective Rubber Coating for the Hulls of Ships. R. DITMAR. (*Z. Angew. Chem.*, xxvi, 565.)—It is stated that coatings composed of rubber mixings, raw or semi-vulcanized, prepared from low-grade rubbers rich in resin, and preferably containing large proportions of factis (a rubber substitute) and inorganic fillers, when pierced by a projectile will close over the hole and so prevent the inrush of water. The coating may be made more resistant to water by adding tar. It is laid on or cemented to the hull of a ship and painted to protect it from attack by marine animals.

THE FRANKLIN INSTITUTE

(Proceedings of the Annual Meeting held Wednesday, January 21, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 21, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 12.

The tellers, Messrs. Colvin, Jennings, and Williams, submitted the report of the ballots cast for President, Vice-President, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Coleman Sellers, Jr., Vice-President (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

John Birkinbine, Walton Forstall, E. Goldsmith, Harry F. Keller, Louis E. Levy, Richard Waln Meirs, Alexander P. Robinson, George D. Rosengarten, Managers (to serve three years), and Marshall S. Morgan, Manager (to serve two years).

The following proposed amendment to the By-laws, presented at the December meeting, was submitted for final action and adopted:

Article III, Section 10 of the By-laws to be amended as follows:

After "Philadelphia" in the second line add: "except that members of the Army and the Navy shall be considered as non-resident members, irrespective of residence," so that the section, as amended, shall read:

"Non-resident members shall be those who reside permanently at a distance not less than twenty-five miles from Philadelphia, *except that members of the Army and the Navy shall be considered as non-resident members, irrespective of residence.* Transfers of membership from the resident to non-resident class may be granted by the Board of Managers at its discretion in cases of temporary absence of a member from the city for a period of not less than one year."

The President then presented a statement of the work of the Institute during the past year, and submitted the reports of the various standing committees.

The paper of the evening, on "The Heat Received by the Earth from Stars and Planets," was presented by Dr. Ernest F. Nichols, President of Dartmouth College, Hanover, N. H. The speaker gave an interesting account of the experiments carried on at the Yerkes Observatory in the summer months of 1898 and 1900, directed toward detecting and, if possible, measuring the heat received from the two stars Arcturus and Vega and the planets

Jupiter and Saturn. The apparatus and experimental methods used, as well as the numerous obstacles which were encountered in the conduct of the work, were fully described. The numerous data recorded during the course of experiments were presented. The subject was illustrated by lantern slides. In the brief discussion which followed the presentation of the paper, Messrs. Levy, Henderson, and Bond participated.

A rising vote of thanks was extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

REPORT OF THE BOARD OF MANAGERS FOR THE YEAR ENDING SEPTEMBER 30, 1913, WITH APPEN- DICES EMBRACING THE ANNUAL REPORTS OF THE VARIOUS COMMITTEES AND SECTIONS.

To the Members of The Franklin Institute:

Your Board of Managers formally present herewith the reports of the standing committees upon the operations of the past year. These reports have been printed, and a copy will be sent to each member of the Institute. The Board hope that you will come from the reading of these reports satisfied that the work of the Institute has been conducted with industry and intelligence by those to whom you have entrusted it.

The Committee on Instruction, Mr. Paul, Chairman, report an increase in the enrolment of students and in the number of graduates for this, the ninetieth consecutive year of the school's activity. The Institute has recently greatly improved its school facilities, and is rewarded therefor by a most gratifying increase in the student roll. The registration of students for the winter term has steadily increased from 173, in 1909, to 306, in 1913, and the number of graduates has increased in practically the same proportion. We have now as many students on our rolls as we can properly care for in the space that we are able to devote to this purpose. Our effort of late has not been to increase the attendance at our schools, but to improve the quality of the service that we render to the individuals and to the community through that branch of our work.

The report of the Committee on Elections and Resignations of Members, Mr. Eglin, Chairman, shows a gratifying increase in the membership—now numbering 1395. We have elected, during the past year, 292 members, which is the largest enrolment for any year since the present rate of dues was established. We have increased nearly 50 per cent. in membership in the past five years. The record of resignation of members shows that the resignations are much less, in proportion to the total enrolment, than we had, unfortunately, become accustomed to expect. This is one of the most convincing and gratifying evidences of an increased interest in the work the Institute is doing for the public good, as well as an increased appreciation of what the Institute does for the individual member.

We learn from the report of the Library Committee, Mr. Levy, Chairman, that there have been 3306 additions to the library during the past year, which is about 10 per cent. more than in the previous year, and 50 per cent. more than the increases in 1909. The library is used more and more largely from year to year. The pressing demands of the library to-day are for increased space and more convenient location.

The report of the Committee on Publications, Mr. Levy, Chairman, while interesting, calls for no special comment. I desire, however, to again call your attention to the JOURNAL. Within the past few years there has been created a board of associate editors, comprising twenty men, of international reputation for scientific work. This is an added, and the most certain attainable, assurance of value and accuracy in our senior publication. The size of the JOURNAL, during the last five years, has been increased about 25 per cent. Its standing in the scientific world, always notable, has been fully maintained.

The Year Book of the Institute, brought out by the Committee on Publications, is a worthy publication, setting out the activities of the Institute, and containing historical notes, the programme of lectures, the charter and by-laws, and a list of the membership.

The Committee on Meetings, Mr. Rogers, Chairman, report monthly meetings from October to May, inclusive, at many of which the capacity of the Hall was overtaxed. The subjects treated covered a wide field of scientific and engineering activity, as will be seen by reference to the JOURNAL for the past year.

The Committee on Sectional Arrangements, Mr. Day, Chairman, report an even better attendance during the past year than in previous years. The committee report sixteen meetings during the year, each with a lecture from some man of acknowledged authority in his line of work. The high standard for these meetings, set for us by our predecessors, is being fully maintained by the members of the Sections and of your Committee on Sectional Arrangements.

The report of the Committee on Exhibitions, Mr. Birkinbine, Chairman, contains no present recommendation, but suggests the possibility of an exhibition in the near future.

The Committee on Museums, Professor Outerbridge, Chairman, presents an interesting report, covering, in the main, a list of gifts received during the year and placed in charge of this committee. Some of these gifts are of great historic interest. The Board respectfully suggest that you, members of the Institute, do not sufficiently appreciate the number and interest of the articles in charge of the Committee on Museums. They are now all available for convenient inspection.

The report of the Committee on Science and the Arts, Mr. Crisfield, Chairman, shows great activity. It contains certain recommendations that will be considered by the Board and by the committee for the year 1914. The committee report the disposition of twenty-seven cases during the year, with seventeen awards made. The report shows the very broad field covered by the committee's efforts; and in the list of awards made will be found the names of men among the most distinguished in their respective branches of scientific work.

The report of the Finance Committee, Mr. Forstall, Chairman, shows that for the year covered by the report the Institute had an income applicable to operating of..... \$29,887.73
that the operating costs were 34,158.42

making a deficit for the year's operation of \$4,270.69

Our financial condition has improved of late years. We have some reason to believe that our days of deficits will soon be past.

In this connection we make the following memorandum of endowments received during the past three years:

John H. Noblit	\$135,922.79
James H. Cresson	50,000.00
Maria Blanchard	10,000.00
Anna Blanchard	10,000.00
Mary Thorn	1,000.00
Charles Longstreth	1,000.00

Through the generosity of Mr. Samuel Insull, of Chicago, we are able to provide an additional and very valuable gold medal, to be known as the Franklin Medal, and to be awarded for general scientific achievement, leaving the Elliott Cresson Gold Medal to be awarded for specific achievement in science. Your Board think this medal makes complete our list of awards, enabling The Franklin Institute to satisfactorily evidence its approval of notable work for the good of mankind in any part of the broad field of science.

Since our last report to you the widow of our good and lamented friend and one-time secretary, Dr. Wm. H. Wahl, has laid down the burden of her mortality. This fact is worthy of record, both because of the distinguished services that Dr. Wahl rendered to the Institute and because of the fact that, under his will, his estate was to descend to the Institute, upon the death of his wife—conditioned on the Institute's raising a sum equal to the value of the estate. The present value of the estate is about \$85,000. It is incumbent upon the membership to secure that this munificence be not lost to us. This award being secured, there will be no further anxiety as to the financial support of the work the Institute is doing for the good of the citizen and of the State.

Your Board have satisfaction in reporting to you the purchase by your Franklin Fund and Building Committee, Mr. Howson, Chairman, of 23,320 square feet of land and the eight residences thereon, fronting Logan Square and the route of the boulevard. The land lies on the southeast corner of Race and Nineteenth streets. The Parkway frontage is 110 feet. Among our near neighbors, when we have secured the necessary further funds and erected a building upon this incomparable site, will be the Cathedral, Wills Eye and Ear Hospital, the Academy of Natural Sciences, and the great and noble new Public Library.

Your Board regard the acquisition of this valuable and improving real estate by the Institute as a notable achievement for the cause of the

scientific advancement of the mechanic arts in the State of Pennsylvania, and congratulate you upon it.

While we look with hope to the day when a new building, larger than this in which we now gather and on the more convenient site, will enable us to better serve the citizen and the State, we will not abate our efforts in the interim to carry on the work of The Franklin Institute in this beautiful and historic building in a manner as nearly may be worthy of the confidence you have shown in us, and of the standards set by the able and devoted men who have preceded us.

WALTON CLARK,
President.

REPORT OF THE COMMITTEE ON INSTRUCTION.

To the Board of Managers:

The Committee on Instruction has been much gratified by the favorable showing made by The Franklin Institute School of Mechanic Arts during the past school year and by the marked increased interest shown by the members of the Institute in the course of Popular Lectures.

The School, now in the 90th year of its existence, opened its winter course in September, 1913, with an enrolment of 306 students, an increase of 20 over the corresponding term of the preceding year. The plan of instruction was similar to that of the previous year, the work of the School being divided into four departments, Drawing, Mathematics, Mechanics and Naval Architecture.

The faculty for the year consisted of:

Professor William H. Thorne, Director and in charge of the Department of Drawing.

Professor William E. Bullock, Assistant Director and in charge of the Department of Mechanics.

Professor H. P. Tyson, in charge of the Department of Mathematics.

Professor H. C. Towle, in charge of the Department of Naval Architecture.

Professor Thorne was ably assisted in his department by Professor Clement Remington, in charge of Architectural and Freehand Drawing, and by Messrs. F. H. Lobb, I. P. Pedrick, C. Rommel and W. W. Twining, Assistants in Mechanical Drawing.

Professor Bullock had in Messrs. Bark and Wheatley very competent assistants.

Throughout the year the classes were well attended and the standard of work was exceptionally good. Seven visits were made on Saturday afternoons during the season to some of the most prominent industrial plants, and also special invitations were given to the students to attend such of the Institute lectures as were of direct interest to them.

The visits made were as follows:

The Ogontz Power Plant of the Phila. Rapid Transit Co.,

The Belmont Pumping Station,

The Power Plant of The Baldwin Locomotive Works,
The University of Pennsylvania Engineering Laboratories,
The United Gas Improvement Co., Station B Works,
The U. S. Navy Yard, League Island,
The Philadelphia Electric Co., 26th and Christian Streets.

The greatest courtesy was shown to the party at each plant visited, and the thanks of the Committee are extended to the management and employees of these establishments for the invitations extended and for the attention bestowed.

The graduating exercises were held in the Hall of the Institute, on the evening of April 18, 1913. Mr. Walton Clark, President of the Institute, occupied the chair, and the graduating address was delivered by Mr. G. R. Henderson, Consulting Engineer of The Baldwin Locomotive Works. Forty-five students were graduated, twenty-six in the Department of Drawing, nine in Mathematics, seven in Mechanics, and three in Naval Architecture; one student was awarded the New York Shipbuilding Company's prize for the student of greatest merit in Naval Architecture; fourteen students in the Department of Drawing received Scholarships from the B. H. Bartol Fund, entitling them to free tuition; forty students were awarded Honorable Mention Certificates for the Winter Term, and thirty-four for the Spring Term. The announcement was made at the graduating exercises that Mr. J. B. McCall, of the Philadelphia Electric Company, had offered a prize for the student of greatest merit in the Department of Mathematics; Mr. Wilfred Lewis offered a similar prize in the Department of Mechanics; the New York Shipbuilding Company again presented a set of drawing instruments to be awarded to the student of greatest merit in the Department of Naval Architecture; the Alumni Association of The Franklin Institute offered special prizes for the most proficient students in Mechanical Drawing, Architectural Drawing, Freehand Drawing, Mathematics and Naval Architecture, and also free membership for one year to graduates in each Department having a 100 per cent. attendance record, or if the total number of graduates having such record is less than ten, to the ten graduates having the best attendance record. The above prizes will be awarded on the results of the present year's work.

The Committee on Instruction has pleasure in reporting that all those connected with the School have shown the utmost zeal in promoting its interest, and the successful year is due to the thoroughness of their instruction and to their earnest co-operation with the Committee.

On January 31, 1913, the first of the Popular Lectures was given at the Institute; the lecturer being Dr. G. F. Stradling, and the subject, "On the Edge of Alaska." This was followed on February 6, by Mr. W. N. Jennings, who spoke on "Camp Life in Philadelphia," and on April 26, Mr. Fred Monsen lectured on "The Trail of the Spanish Pioneer." That the lectures were thoroughly appreciated, was attested by the enthusiasm of the large audiences.

Our thanks are extended to those gentlemen who have so generously given their services in the course of popular lectures referred to above, and who, by their help, have greatly assisted the Institute in its educational work.

Summary of the School Registration as compared with the preceding year :

	Winter Term		Spring Term	
	1912-1913	1913-1914	1912-1913	1913-1914
Drawing	158	188	132	..
Mathematics	61	71	39	..
Mechanics	38	30	23	..
Naval Architecture	29	17	23	..
	286	306	217	..

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 14, 1914.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS.

To the Board of Managers:

During the fiscal year, ending September 30, 1913, there were two hundred and ninety-one members enrolled; resignations were received and accepted from thirty-one members; and deaths were recorded of nineteen members. Four resident members were transferred to the non-resident class, and one non-resident to the resident class.

The figures for the several classes of membership and for the two preceding years follow:

<i>Elections:</i>	1910-11.	1911-12.	1912-13.
Resident Members	28	68	101
Non-Resident Members	15	33	186
Associate Members	5	7	1
Honorary Members	0	1	0
Life Members	4	1	3
	52	110	291
<i>Resignations:</i>	1910-11.	1911-12.	1912-13.
Resident Members	12	27	16
Non-Resident Members	12	13	13
Associate Members	0	1	2
	24	41	31
<i>Deaths:</i>	1910-11.	1911-12.	1912-13.
Resident Members	16	9	8
Non-Resident Members	5	4	4
Life Members	9	11	6
Honorary Members	0	1	1
Associate Members	0	1	0
	30	26	19

<i>Summary:</i>		1912-13.
Total Elections		291
Total Resignations	31	
Total Deaths	19	
	—	50
Net increase in membership		241

It will be noted that there has been a net increase in membership of 241, the net increase during the preceding year being only 43, showing a very substantial gain in membership. It is hoped that this increase can be continued during the coming year, as the improved work which the Institute is doing is attracting more general interest.

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 14, 1914.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE.

Financial Statement, October 1, 1912, to September 30, 1913.

PROPERTY AND FUNDS.

Building and land, 13-17 S. Seventh Street	\$60,000.00	
Library	100,000.00	\$160,000.00
<hr/>		
	Principal.	Unexpended Income.
Funds held by Board of Trustees	\$264,528.48	\$273.73
Funds held by Board of Managers...	23,478.50	62.96
Franklin Institute Building Fund	371,185.16	....
Elliott Cresson Medal Fund	1,000.00	2,082.50
Franklin Fund and Building Committee.	886.59	....
<hr/>		<hr/>
Total funds	\$661,078.73	\$2,419.19
		\$663,497.92
<hr/>		<hr/>
Grand total		\$823,497.92

LIABILITIES.

Certificates of stock	\$30,420.00
Mortgage on Institute Building (held by Trustees as investment for funds)	21,325.00
Bills payable	22,250.00
Accounts payable	5,096.41
Unearned income	1,494.24
<hr/>	
Grand total	\$80,585.65

INCOME AND EXPENSES APPLICABLE TO YEAR ENDING SEPTEMBER 30.

Income.

Dues		\$9,740.31
Initiation fees		910.00
General Endowment Fund		9,375.82
James H. Cresson Memorial Fund		1,091.45
Estate of John Turner		129.15
Estate of Robert Wright		1,394.55
Miscellaneous		19.00
Membership badges		6.50
Instruction: Drawing	\$1,414.50	
Mathematics	512.25	
Mechanics	307.24	
Naval Architecture	389.76	2,623.75
Publications: Subscriptions and sales	\$1,817.55	
Advertising	2,779.65	4,597.20
Total		\$29,887.73

Expenses.

Building: Wages	\$1,153.50	
Repairs and maintenance	429.17	
Heat, light, and power	655.30	
Taxes, water rent, and insurance	581.68	
Miscellaneous supplies and expense	221.14	3,040.79
Elections and resignations		360.41
Instruction: Drawing	\$1,145.62	
Mathematics	298.09	
Mechanics	203.11	
Naval architecture	233.23	
Popular lectures	109.19	
Miscellaneous expense	774.66	2,763.90
Library: Salaries	\$3,763.43	
Books and periodicals	1,641.29	
Binding	663.00	
Miscellaneous expense	234.44	6,302.16
Meetings		494.45
Office and General: Salaries	\$8,191.14	
Office expense	501.66	
General expense	1,269.87	9,962.67

Publications: Printing	\$5,543.25	
Reprints	248.32	
Illustrating	661.16	
Miscellaneous expense	465.48	
Year-Book	497.02	7,415.23
		<hr/>
Science and Arts		1,382.68
Sections		939.05
Interest and discount		1,497.08
		<hr/>
Total		\$34,158.42
Net expense		4,270.69

During the fiscal year there has been an increase in funds as follows:

General Endowment Fund	\$225.00
James H. Cresson Memorial Fund	50,000.00
Edward Longstreth Medal Fund	1,000.00
Elizabeth M. Graff Fund	14.38
Franklin Institute Building Fund	11,104.94
Franklin Fund and Building Committee ...	68.29

The mortgage on the Institute building has been decreased by \$750.00.
Bills payable have been increased by \$5,000.00

The excess of expense over income for the year was \$4,270.69.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 14, 1914.

REPORT OF THE COMMITTEE ON PUBLICATIONS.

To the Board of Managers:

The principal publications in charge of this committee are the JOURNAL of the Institute and its Year-Book. The contents of the JOURNAL have been maintained during the past twelve months on the high plane of excellence to which these had been advanced during the preceding year. Through the collaboration of the corps of associate editors organized in 1912, the JOURNAL has been brought to occupy again that conspicuous place as a chronicle of progress in science and the arts which it held with such marked distinction during the greater part of the 19th century. This distinction became gradually diminished as the journalistic field of practical technology and of the various industrial arts became increasingly occupied by publications devoted to individual trades, and by those of specifically professional organizations. The very growth, however, of these specialized publications, whose scope can at best but scarcely extend beyond the range of daily practice, has resulted in leaving a larger place for a chronicle of original research in the application of science in the arts, and this place our distinguished collaborators are efficiently helping us to fill.

Of those whose help in this direction we obtained at the beginning, eighteen months ago, two, namely Dr. Weston and Dr. Whitney, found it

necessary to relinquish the work, their places being taken by Dr. Wilder D. Bancroft, Professor of Physical Chemistry, Cornell University, and Dr. W. J. Humphreys, Professor of Meteorological Physics, U. S. Weather Bureau. Our esteemed colleague, Mr. Edwin S. Balch, having, after many years of helpful service on this Committee, resigned his membership, Dr. George A. Hoadley was appointed to fill the vacancy.

The Year-Book of the Institute, like the JOURNAL, has been kept up to the standard latterly set for it, as regards not only the completeness and accuracy of its contents, but its mechanical make-up as well. In both respects this publication now properly reflects the dignity of The Franklin Institute.

The financial aspects of the committee's work may be briefly summarized as follows:

The receipts from all sources, including the credits due the publication account for the additions to the library through exchanges of the JOURNAL for other scientific periodicals and exchanges of advertising space for books, amounted to \$6,493.05, and the expenditures to \$6,356.53. The surplus of \$136.52 is due principally to receipts from reprints, there having been a decrease of \$146.60 in our income from other sources.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

PHILADELPHIA, January 14, 1914.

REPORT OF THE COMMITTEE ON EXHIBITIONS.

To the Board of Managers:

The Committee on Exhibitions calls attention to the number of displays which have been features of large conventions, held in various portions of the country, and to the success of most of these, which may be interpreted as demonstrating a desire of the public for exhibitions.

The facilities for such displays in Philadelphia are limited, and the cost of a satisfactory building to accommodate an exhibition, such as The Franklin Institute should sponsor, would necessitate efforts to accumulate a fund which might interfere with securing money for the new Institute home.

The Committee, however, believes that when the buildings covering the site selected for the permanent housing of the Institute are razed, there may be available space which could be used for a temporary structure, or possibly some of the area allotted to Parkway can be secured for such purpose.

The Committee believes that an exhibition devoted to special features would be more desirable than to attempt a general exposition, but at the present time has no recommendation to make.

It will, however, keep advised as to the progress made for the Panama Exposition, having in mind the possibility of securing some of the exhibits, if the time immediately preceding or following the California enterprise coincides with opportunity to secure available accommodations in Philadelphia.

Respectfully submitted,

JOHN BIRKINBINE,
Chairman.

PHILADELPHIA, January 14, 1914.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

To the Board of Managers:

The Committee on Sectional Arrangements begs to report that during the year ending September 30, 1913, sixteen lectures were given by men of national prominence, covering a wide range of subjects of unusual interest and great practical value.

The average attendance was slightly better than that for the preceding year. Following is the list of lectures:

PHYSICS AND CHEMISTRY SECTION. March 13, 1913.

Seven Meetings.

October 3, 1912.

Industrial Research.

Robert Kennedy Duncan, B.A., Sc.D.; Director Industrial Research and Professor of Industrial Chemistry, University of Pittsburgh and University of Kansas; lecturer at Clark University.

November 7, 1912.

The Chemistry of Nutrition.

R. H. Chittenden, Sc.D.; Director Sheffield Scientific School, Yale University.

December 12, 1912.

Chemiluminescence.

Wilder D. Bancroft, Ph.D.; Professor of Physical Chemistry, Cornell University.

January 30, 1913.

The Physical Laboratory of the National Electric Light Association.

Edward P. Hyde, Ph.D., Director of Physical Laboratory N.E.L.A.

March 6, 1913.

Electricity and Matter.

Arthur W. Goodspeed, Ph.D., Professor of Physics, University of Pennsylvania.

The Chemistry of Paper Making.

Arthur D. Little, Chemical Engineer; President Arthur D. Little, Inc.; Special Lecturer Massachusetts Institute of Technology.

April 10, 1913.

Colloids and Crystals—The Two Worlds of Matter.

R. H. Bradbury, Ph.D.; Head of Dept. of Science, Southern High and Manual Training School.

ELECTRICAL SECTION.

Two Meetings.

January 9, 1913.

The Electrical Propulsion of Ships.

W. L. R. Emmet, Sc.D.; Consulting Engineer and Engineer of Lighting Department U. G. I.

April 3, 1913.

The Electrical Equipment of a Modern Battleship.

H. A. Hornor, B.A.; Electrical Engineer New York Ship Building Company.

MECHANICAL AND ENGINEERING
SECTION.

Five Meetings.

October 10, 1912.

The Testing of Full-Size Pieces
under Practical Conditions,
together with Locomotive
Testing in the United States.

Cav. Gaetano Lanza, the Bald-
win Locomotive Works.

October 24, 1912.

Safety of Life at Sea.

Mr. James Donald, Consulting
Naval Architect, Fore River
Ship Building Company.

December 5, 1912.

Recent Advances in the Steam
Turbine Art.

Mr. H. T. Herr, V.P. and Gen.
Mgr. Westinghouse Machine
Company.

April 24, 1913.

Industrial Combustible Gases.
Mr. J. M. Rusby, Engineer of
Tests, United Gas Improve-
ment Company.

May 1, 1913.

The Design of Large Bridges
with Special Reference to
the New Quebec Bridge.

Ralph Modjeski, D.Sc.; Con-
sulting Engineer; American
Member of the Commission
which designed the New
Quebec Bridge.

MINING AND METALLURGICAL
SECTION.

Two Meetings.

November 14, 1912.

Experimenting with the Elec-
tric Furnace.

F. A. J. FitzGerald, A.B.,
B.S.; FitzGerald & Bennie
Laboratories.

February 13, 1913.

An Outline of the Metallog-
raphy of Iron and Steel.

Albert Sauveur, B.S.; Profes-
sor of Metallurgy and Metal-
lography, Harvard Univer-
sity.

All of the lectures, except Professor Duncan's, were illustrated by lantern slides and, in addition, practical demonstrations were presented by Dr. Bancroft and Dr. Bradbury.

Thirteen of the lectures have been published in the JOURNAL.

Dr. A. A. Michelson, of the University of Chicago; Dr. Harry F. Keller, of the Philadelphia High School, and Professor M. E. Cooley of the University of Michigan, were unable to be present upon the dates set for their lectures, but it is hoped that arrangements may be made to hear them during the coming year.

Respectfully submitted,

CHARLES DAY,
Chairman.

PHILADELPHIA, January 14, 1914.

REPORT OF THE ENDOWMENT COMMITTEE.

To the Board of Managers:

The Committee announces the death of Mrs. William H. Wahl, which occurred on December 16, 1913. According to the terms of the will of Dr. William H. Wahl, deceased, The Franklin Institute becomes the residuary legatee, providing that the Institute, within three years from the date of Mrs. Wahl's death, obtains, by subscription or by appropriation from the City of Philadelphia, or the State of Pennsylvania, or by gift from a source other than by bequest, a sum equal to the appraised value of the estate.

We have not, as yet, received a full account of the estate from the executors and trustees under the will, The Philadelphia Trust Company, but we have in our possession a memorandum which shows that the Real Estate is assessed at \$25,660, and that the Personal Estate is assessed at \$59,085, making a total of \$84,745. We believe that it will be necessary for the Institute to raise at least \$90,000 within three years in order to receive this bequest.

This bequest is to be known as the "John H. Wahl Fund" in memory of Dr. Wahl's father.

At a meeting of the Endowment Committee, January 7, 1914, it was decided to at once prepare and send a letter to each member of the Institute, setting forth this bequest and asking for subscriptions to help meet the requirements of the will. One subscription has already been received.

The Endowment Committee takes pleasure in announcing that Mr. Samuel Insull, of Chicago, Illinois, has given the sum of \$6,000, which is to be known as "The Franklin Medal Fund, founded January 1, 1914, by Samuel Insull;" \$1,000 of this amount is to be used for securing the proper design and the necessary dies and diplomas. The remaining \$5,000 is to be invested and is to be used in awarding the Franklin Medal to those workers in Physical Science and Technology, without regard to country, whose efforts have, in the judgment of the Managers of the Institute, been most productive in advancing Physical Science and its applications.

The committee also announces the generous gift by Miss Mary Thorn of one thousand dollars for the establishment of scholarships in the School and three hundred dollars for a Permanent Resident Membership.

Respectfully submitted,

PHILADELPHIA, January 14, 1914.

HENRY HOWSON,
Chairman.

REPORT OF THE COMMITTEE ON LIBRARY.

(Abstract.)

To the President and Members of The Franklin Institute:

During the twelve months ending September 30, 1913, the contents of the library were increased by 3306 additions, this number being 335 more than the additions of the preceding year. The new accessions were derived as follows:

SOURCE.	Bd. Vols.	Unbd. Vols.	Pphs.	Maps.
Gift	439	528	1555	1
Exchange account	25	5		
JOURNAL	28	36	46	
By purchase:				
Institute appropriation	36	11	1	
Lea Fund	4	2		
Moore Fund	102	15	1	
Morris Fund	23	2		
Potts Fund	14	5		
Binding:				
Institute Appropriation	405			
Chemical Periodical Binding Fund	22			
	1098	604	1603	1

Gifts of books, pamphlets, and periodicals in large quantities or of special value were received as follows:

- Mr. H. M. B. Bary, copies of engineering publications.
- Mr. George S. Cullen, volumes of the *Jewellers' Circular* and other publications.
- Dr. E. V. d'Invilliers, books, pamphlets, and magazines on geology, mining, etc.
- Mr. Spencer Fullerton, pamphlets and magazines on various subjects.
- Mr. F. Lynwood Garrison, volumes and pamphlets on mining and related subjects.
- Mr. Richard Gilpin, volumes and pamphlets on electrical subjects.
- Mr. J. A. Given, copies of the *Electrical Engineer*, *Electrical World*, *American Electrician*, and *Electrician*.
- Mr. H. B. Hackett, books and pamphlets on electricity and engineering.
- Mr. Robert R. Kitchel, copies of *Iron Trade Review* and *Engineering Record*.
- Mr. Thomas M. Lightfoot, books pamphlets, and magazines on engineering subjects.
- Mr. Richard Waln Meirs, eight bound volumes.
- Mr. E. H. Sanborn, collection of clippings on iron and steel taken from newspapers and magazines, classified and arranged in filing cases.
- Mr. Wm. R. Webster, volumes of publications of engineering societies.
- Mrs. Martha C. Heckendorn, volumes from the library of the late Henry C. Heckendorn.
- The Baldwin Locomotive Works, U. S. Patent Office Reports.
- Henry Bower Chemical Manufacturing Company, chemical publications and patent reports.
- The Engineers' Club of Philadelphia, engineering periodicals and magazines of the year 1912.
- Messrs. Harris & Richards, books, pamphlets, and magazines on engineering and architectural subjects.

Koenigliche Technische Hochschule zu Muenchen, fifty-five pamphlets consisting of dissertations and other publications.

The committee is again indebted to Mr. Joseph A. Arnold, Editor and Chief, Division of Publications, U. S. Department of Agriculture, for supplying the library with copies of the current publications of the department.

NON-TECHNICAL MATERIAL AND PUBLIC DOCUMENTS.

The year's accumulation of duplicate public documents and non-technical publications was transferred to the Free Library. The material so disposed of amounted to 110 volumes and four pamphlets.

CONTENTS OF THE LIBRARY.

After deducting the duplicate books withdrawn and discarded during the year, the library contained, at the close of the Institute year on September 30th, 1913:

Volumes, bound and unbound	64,169
Pamphlets	48,648
Maps and charts	2,272
Photographs	1,336
Newspaper clippings	192
Manuscripts	34

BINDING.

The following bookbinding was done for the library:

	Bound	Repaired	Rebound
Recent volumes of periodicals	405		
Recent volumes of periodicals charged to Chemical Periodical Binding Fund	22		
Old volumes	132	21	3
Books purchased with the income of the Lea Fund	15		
Memorial Library Fund	2		
Moore Fund	31		
Morris Fund	3		
Potts Fund	2		
Books received from the JOURNAL	3		
	<hr/> 615	<hr/> 21	<hr/> 4

REMARKS.

Additions.

The continued increase in the accessions is due in a large measure to the systematic efforts which are being made to obtain all technical publications of which notices appear in the current magazines.

The committee is indebted to the donors above mentioned for their contributions.

List of Serials.

Among the special work undertaken during the year is the preparation of a list, on cards, of the status of the current periodical sets in the library. This list will present an accurate statement of the condition of the file of each periodical—when first issued, how many volumes have appeared, and, if incomplete, what parts are missing. The progress on this work is slow because of the care required in its preparation and the limited time which can be devoted to it. It is, however, expected that in the course of another year this list of periodical publications will be finished. When this is done, such sets as have ceased publication or which are no longer received by the library will be listed in the same manner.

Pamphlets.

The pamphlets on mechanical subjects are being kept together, and when a sufficient number on one subject are accumulated these will be bound and properly placed on the book shelves.

It is the intention of the committee to have the remaining pamphlets, which are still stored, gone over and classified according to subjects; each class to be treated as were those relating to mechanics. In this way the entire accumulation of pamphlets, many of which are of considerable importance, will eventually be converted into bound volumes, duly catalogued and made accessible.

Stack Room.

The stack room is again very much crowded, but the shelving in the basement, to which reference was made in last year's report, will shortly be ready, and some of the periodical sets which are rarely consulted will be removed to those shelves. It is estimated that about 3200 volumes can be accommodated in the basement rooms, and this will greatly relieve the present overcrowding in the stack.

LIBRARY PUBLICATIONS.

Bulletin No. 3, which will contain the additions to the library during the past two years, is now in course of preparation and will shortly be printed and published.

Respectfully submitted,

LOUIS E. LEVY,
Chairman ad int.

PHILADELPHIA, January 14, 1914.

REPORT OF THE COMMITTEE ON MUSEUMS.

To the President and Members of The Franklin Institute:

The Committee on Museums begs respectfully to report that during the year now closing quite a number of interesting and valuable gifts have been added to the collection of models, memorabilia, etc., partly owing, no doubt, to the revived interest shown in the collection since the completion of the onerous task of bringing out, repairing, classifying, and displaying the large

number of articles that had been stored away out of sight for years. A brief account of this work of resuscitation was given in the last annual report of this Committee.

The Institute's collection of models has been taken good care of during the year and the additional models have been accommodated as well as possible.

To display the models to their best advantage would require much more space than is now available. It is expected that with the maturing of plans now in prospect for providing the Institute with a new building, ample provision will be made for the Institute's Museum; meanwhile an endeavor has been made to house the models and preserve them.

A list of gifts received during the year and placed in charge of the committee is appended.

Respectfully submitted,

ALEX. E. OUTERBRIDGE, JR.,

PHILADELPHIA, January 14, 1914.

Chairman.

APPENDIX.

*Gifts to the Institute during the year October 1, 1912, to September 30, 1913.
Placed in charge of the Committee on Museums.*

Nitrogen-filled Tungsten Lamp, 110 volts, 1000 C. P. Gift of Mr. J. W. Lieb, Vice-President, The New York Edison Company.

Edison Z-Type Dynamo. 17.6 K. W., 110 volts. Gift of The William Cramp and Sons Ship and Engine Building Co. This machine was in service in the power house of the company until the spring of 1913.

Herrick Balanced Rotary Engine, 110 H. P., designed and developed by Mr. Gerard P. Herrick, President Gerard Development Company. Gift of the designer.

Deed, dated 1787, bearing an excellent signature of Benjamin Franklin. Gift of Mr. Lawrence T. Paul.

Apparatus used in experiments on Vortex Motion in Liquids by Dr. E. F. Northrup, Princeton University. Gift of the experimenter.

Edison Three-Wire Chemical Meter, No. 102. Gift of Mr. G. L. Thompson, General Electric Company.

Cell used by Mr. Samuel Rea and Mr. Jesse Lightfoot in original experiments in which willow charcoal was made to glow with electric current. Gift of Mr. Thomas M. Lightfoot.

Framed photograph of the late Joseph M. Wilson, President of the Institute, 1887 to 1896. Gift of Mr. Wilson's brother, Mr. Henry W. Wilson.

Collection of Alundum Refractories. Gift of the Norton Company.

Medals granted to Mr. J. E. Wootten (Paris Exposition, 1878; John Scott Legacy Medal, 1891; National Exposition of Railway Appliances, 1883, presented by Philadelphia and Reading Railroad 1884). Gift of Mrs. Augustus W. Hoff.

Framed photograph of Mr. John E. Wootten. Gift of Mrs. Augustus W. Hoff.

Case of Electrical Fittings. Gift of the Bryant Electric Co.

Early form of Steam Engine Indicator, invented by Wm. Macnaught, Glasgow, and used on steamboat "Richard Stockton." Gift of Mr. W. F. Carnes, Harlan and Hollingsworth Corporation.

Hirsch Electric Cap Lamp for use in mines. Gift of the Hirsch Electric Mine Lamp Co.

First Model of Ellis Adding Typewriter. Gift of Mr. Halcolm Ellis.

Autograph letter from John Tyndall, Royal Institution of Great Britain, dated June 12, 1882, to A. E. Outerbridge, Jr., referring to "a very important observation made by General Duane on the Coast of the United States," and autograph letter from Sir Frederick Bramwell, dated London, December 4, 1882, to A. E. Outerbridge, Jr., referring to "Sterlings Toughened Cast Iron," and enclosing patent specification No. 11,262 issued in 1846. Gifts of Prof. A. E. Outerbridge, Jr.

REPORT OF COMMITTEE ON MEETINGS.

To the President and Members of The Franklin Institute:

During the year ending September 30, 1913, eight stated meetings were held.

At the May meeting the Institute's Elliott Cresson Medal was presented to Dr. Chas. P. Steinmetz, Dr. Isham Randolph, and Mr. Emile Berliner. The presentations were made by President Walton Clark, and were followed by addresses from each of the recipients of the medal.

Under arrangements made by the Committee on Meetings, with the coöperation of the Secretary's office, papers were presented at the meetings as follows:

October 16, 1912: "Recent Developments in Radiography." Mr. H. Clyde Snook.

November 20, 1912: "The Railway Tunnels of New York City." Dr. Alfred Noble.

December 18, 1912: "The Engineer in the Building of the Republic." Dr. Isham Randolph.

January 15, 1913: "Applications of the Gyroscope to Marine Purposes." Mr. Elmer A. Sperry.

February 19, 1913: "Transmission of Electrical Energy." Prof. Elihu Thomson.

March 19, 1913: "The Generation and Distribution of Energy." Mr. Samuel Insull.

April 16, 1913: "The Wireless Telephone." Prof. G. W. Pierce.

May 21, 1913: "Development of the Talking Machine." Mr. Emile Berliner.

"The Imaginative Faculty in Engineering." Dr. Isham Randolph.

"Some Electrical Problems Awaiting Solution." Dr. Chas. P. Steinmetz.

These papers were referred to the Committee on Publications, and afterwards, with the exception of one, were published in the JOURNAL.

JAMES S. ROGERS,
Chairman.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract.*)

To the President and Members of The Franklin Institute:

I am glad to report that the work of the Committee on Science and the Arts for the past year has been excellent. All meetings of the Committee have been well attended and a larger number of cases have been examined and reported upon than for a number of years. The result has been that more honors than usual have been conferred by the Institute.

As a further means, however, of increasing the effectiveness of the Committee's work, the following suggestions are respectfully submitted:

First.—That the work of the Committee be made more generally known to the Institute membership and others interested in the Institute's work.

Second.—That the services of specialists, non-members of the Committee among the Institute's membership and among scientific people generally be sought to assist the Committee in its work. While its membership is large, the extent of the field covered by the work of the Committee is so great that difficulty is sometimes experienced in naming a sub-committee who have had the necessary experience in relation to the subject of the application.

Third.—That the work of the sub-committees on Preliminary Examination and on New Subjects and Publicity be merged into one committee, consisting of ten members, and known as the Sub-committee on New Subjects and Preliminary Examination, and that this Committee address the Institute membership and others through the Secretary of the Institute concerning the work of the Committee and asking for information relating to the work of meritorious inventors.

Fourth.—That as fewer people than desired in this country and abroad are familiar with the Institute's work in stimulating invention and discovery in physical science, it is thought that the Secretary of the Institute might arrange with the various principal scientific and technical journals to give a wider publicity to the work of this Committee, to the end that the Institute may render further assistance to inventors and scientists.

Fifth.—That an effort be made to reach the younger and less well-known members of the body of inventors and scientific workers; though their work may not entitle them to the highest awards of the Institute, yet much of it is meritorious and might be recognized by our Certificate of Merit. In order to attain a knowledge of such improvements and minor advances in the mechanic arts, which though small individually in the aggregate materially assist in the development of these arts, our present methods of obtaining such information will have to be extended. It is suggested that the Secretary of the Institute prepare a circular letter, to be sent to engineering firms, manufacturing establishments, and public service corporations, describing the work of this Committee and asking for the names of deserving young men who have invented (not necessarily patented) novel and useful devices.

Sixth.—That the Secretary of the Institute prepare each year a summary of the awards which have been made during the year so that the value of the

work of the Institute through its Committee on Science and the Arts in promoting invention and scientific discovery may be more readily estimated.

Seventh.—That as a means of bringing the members of the Committee into closer social relationship and as furnishing an opportunity for the informal interchange of ideas, arrangements be made for a simple Science and Arts dinner prior to a meeting of the Committee.

As retiring Chairman I hope, Mr. President and gentlemen, that you will allow me to say to my fellow members that I have derived both pleasure and profit from my connection with them in their work of the past year.

Respectfully submitted,

J. A. P. CRISFIELD,
Chairman.

PHILADELPHIA, January 14, 1914.

APPENDIX TO REPORT OF CHAIRMAN OF THE COMMITTEE ON SCIENCE AND THE ARTS.

STATEMENT OF COMMITTEE'S OPERATION
FOR THE
TWELVE MONTHS ENDING SEPTEMBER 30, 1913.

Cases.

Cases pending, October 1, 1912	5
Applications during the year	16
Other cases opened	24
	40
	—
	45
Disposed of during the year	27
	—
Leaving pending October 1, 1913	18

Disposition of Cases.

Elliott Cresson Awards	7
Edward Longstreth Awards	5
Howard N. Potts Awards	1
John Scott Legacy Recommendations	4
Certificates of Merit	0
Advisory	10
	—
	27

DETAILS OF AWARDS.

ELLIOTT CRESSON MEDAL.

Emile Berliner, in recognition of important contributions to telephony and to the science and art of sound reproduction.

Emil Fischer, in recognition of numerous contributions of fundamental importance to the science of organic and biological chemistry.

Isham Randolph, in recognition of distinguished achievement in the field of civil engineering.

Sir William Ramsay, in recognition of numerous discoveries of far-reaching importance in the science of chemistry.

Lord Rayleigh, in recognition of extended researches of signal importance in physical science.

Albert Sauveur, in recognition of his numerous and important contributions to the science of metallography.

Charles Proteus Steinmetz, in recognition of successful application of analytical method to the solution of numerous problems of first practical importance in the field of electrical engineering.

HOWARD N. POTTS MEDAL.

William A. Bone, for his paper on "Surface Combustion," published in the JOURNAL.

EDWARD LONGSTRETH MEDAL OF MERIT.

Cleveland Abbe, for his paper on "The Obstacles to the Progress of Meteorology," published in the JOURNAL.

E. Leon Chaffee, for his paper on "A New System of Impact Excitation of Continuous Electrical Oscillations," published in the JOURNAL.

Harry C. Jones, for his paper on "The Nature of Solution," published in the JOURNAL.

I. N. Knapp, for his paper on "Natural Gas, with Incidental Reference to other Bitumens," published in the JOURNAL.

John Stone Stone, for his paper on "The Practical Aspects of the Propagation of High-Frequency Electric Waves along Wires," published in the JOURNAL.

JOHN SCOTT LEGACY MEDAL AND PREMIUM.

Awarded by the City of Philadelphia on the recommendation of The Franklin Institute.

Milton A. McKee, for his Process of Treating Printing Plates.

Harley Clifford Alger for his Liquid Measurer.

Halcolm Ellis, for his Adding Typewriter.

C. Francis Jenkins, for his Motion Picture Apparatus.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 7, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, PA., January 7, 1914.

MR. J. A. P. CRISFIELD *in the Chair.*

The following reports were presented for first reading:

No. 2524.—Sperry's Gyro-Compass.

No. 2530.—Stumpf's Una-Flow Engine.

No. 2534.—Reno's Escalator.

No. 2542.—Batdorf Coin Counting and Wrapping Machine.

No. 2544.—Draeger's Pulmotor. Advisory. Adopted.

No. 2587.—Spielman's Cloth Cutting Machine.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the section was held in the Hall of the Institute on Thursday, January 8, 1914, at 8 o'clock p.m., with Dr. George A. Hoadley in the chair.

C. G. Abbott, S. M., of the Smithsonian Institution, Washington, D. C., delivered an address on "Physics of the Sun—A Review of Recent Solar Research." In the lecture especial stress was laid on the study of the solar radiation by means of the spectroscope, spectroheliograph, bolometer, and radiometer. The work of this nature conducted by the Astrophysical Laboratory of the Smithsonian Institution in Washington and elsewhere in the United States, and also in northern Africa, was described at length. The lecture was copiously illustrated with lantern slides of solar phenomena and of astrophysical laboratories and apparatus. The paper was discussed, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, January 15, at 8 o'clock. Mr. G. R. Henderson occupied the chair.

The minutes of the previous meeting were approved as published. The Chairman introduced Mr. Rudolph Hering, Consulting Engineer and Sanitary Expert, New York City, who delivered a lecture on "Sewage Treatment."

Mr. Hering presented the modern experiences and views on the problems of collecting and treating the sewage of cities. Mr. Hering described various methods of purifying fluid sewage in septic tanks, coarse grain and sand filters, and also Imhof tanks. He then described the methods of treating solid sewage. His remarks were illustrated by lantern slides.

At the close of the lecture the subject was discussed by several of the members present. The thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting, Board of Managers, January 14, 1914.*)

RESIDENT.

MR. A. F. KUNBERGER, 1706 North Broad Street, Philadelphia, Pa.

MR. R. A. MILLAR, Westinghouse Machine Company, Philadelphia, Pa.

MR. MARSHALL S. MORGAN, 1401 Arch Street, Philadelphia, Pa.

NON-RESIDENT.

- MR. WM. I. BALLENTINE, 31 The Cambridge, Penn and Michigan Streets, Indianapolis, Ind.
DR. ELMER L. CORTHELL, North Egremont, Mass.
MR. J. E. GREINER, Fidelity Building, Baltimore, Md.
MR. D. W. LUM, Southern Railway Company, 1300 Pennsylvania Avenue, Washington, D. C.
MR. L. P. SHARPLES, West Chester, Pa.
MR. R. JOHN TITZEL, 40 Wall Street, New York, N. Y.
MR. J. A. L. WADDELL, 1012 Baltimore Avenue, Kansas City, Mo.
MR. FRED H. WAGNER, Bartlett Hayward Company, Baltimore, Md.

ASSOCIATE.

- MR. RICHARD GREENWOOD, 4647 Leiper Street, Frankford, Philadelphia, Pa.

Changes of Address.

- MR. C. W. BARWIS, P. O. Box 286, Gallitzin, Pa.
MR. W. E. FIRTH, Midvale Steel Company, Box 1606, Philadelphia, Pa.
MR. ANDREW W. HILL, 1917 South Broad Street, Philadelphia, Pa.
MR. W. N. JENNINGS, 113 A Commercial Trust Building, Philadelphia, Pa.
MR. H. J. KALTENTHALER, 625 West Upsal Street, Germantown, Philadelphia, Pa.
MR. EARL B. SMITH, U. S. Office of Public Roads, Fourteenth and B Streets, S. W., Washington, D. C.
MR. EDWIN D. TUCKER, 308 West One Hundredth and Fourth Street, New York City, N. Y.

NECROLOGY.

Prof. William Dennis Marks, consulting engineer and statistician, New York.

Mr. Theodore H. Morris, 1608 Market Street, Philadelphia, Pa.

Mr. Wallace B. Riegner, Engineer of Bridges, Philadelphia & Reading Railway, Philadelphia, Pa.

Mr. William Tatham, 1811 Walnut Street, Philadelphia, Pa.

LIBRARY NOTES.**Purchases.**

- American Annual of Photography, vol. 28, 1914.
AMOS, P. A.—Processes of Flour Manufacture. 1912.
BEST, W. W.—Science of Burning Liquid Fuel. 1913.
British Association for the Advance of Science.—Reports of the Committee on Electrical Standards. 1913.
BURR, W. H.—Suspension Bridges, Arch Ribs, and Cantilevers. 1913.

- CHRISTIAN, M.—Disinfection and Disinfectants. 1913.
- CLASSEN, A.—Quantitative Analysis by Electrolysis. Ed. 5. 1913.
- COHEN, J. B.—Organic Chemistry. 2 volumes. 1909, 1913.
- COHNHEIM, O.—Chemie der Eiweisskörper. 1911.
- CROSS, C. F., and BEVAN.—Researches on Cellulose. 2 volumes. 1895-1905; 1906 and 1907.
- DEINHARDT, K., and A. SCHLOMANN.—Illustrated Technical Dictionary in Six Languages. Volumes 5-11. 1909-1913.
- DREYER, J. L. E., comp.—Scientific Papers of Sir Wm. Herschel. 2 volumes. 1912.
- Geologisches Zentralblatt.—General Register. Volumes 1-15. No date.
- HAAS, P., and T. G. HILL.—Chemistry of Plant Products. 1913.
- HALSEY, F. A.—Handbook for Machine Designers and Draftsmen. 1913.
- HEATH, T.—Aristarchus of Samos, the Ancient Copernicus. 1913.
- HOUGH, R. B.—American Woods. Part 13. 1913.
- INGERSOLL, L. R., and O. J. ZOBEL.—Mathematical Theory of Heat Conduction. 1913.
- Jahrbuch für Photographie. 1913.
- JUNKERS, H.—Investigations and Experimental Researches for the Construction of my Large Oil Engine. No date.
- KREMANN, R.—Application of Physico-chemical Theory. 1913.
- LEA, M. C.—Kolloides silber und die Photohaloide. 1908.
- London Chemical Society.—Annual Reports of Progress. Volumes 1-9. 1904-1912.
- LUEPPO-CRAMER.—Kolloidchemie und Photographie. 1908.
- Photograms of the year. 1913.
- REDWOOD, B.—Petroleum. 3 volumes. 1913. 3rd edition.

Gifts.

- American Institute of Mining Engineers, Transactions, vol. 44. 1912. New York, 1913. (From the Institute.)
- American Society of Mechanical Engineers, Condensed Catalogues of Mechanical Equipment. December, 1913. New York, 1913. (From Dr. R. B. Owens.)
- Amsterdam Koninklijke Akademie van Wetenschappen: Proceedings of the Section of Sciences, vol. 15. pts. 1 and 2. Verhandelingen, deel 11, Nos. 5 and 6, and Jaarboek, 1912. Amsterdam, 1913. (From the Akademie.)
- Baylor University, Annual Report of the President, 1912-1913. Waco, Texas, 1913. (From the University.)
- Dartmouth College, Catalogue 1913-1914. Hanover, N. H., 1913. (From the College.)
- Electrical Blue Book, 6th edition, 1913. Chicago, 1913. (From Dr. R. B. Owens.)
- Harvard University, Catalogue 1913-14. Cambridge, Mass., 1913. (From the University.)
- Haverhill Public Library, 38th Annual Report, 1912. Haverhill, Mass., 1913. (From the Library.)

- Illinois State Water Survey, Bulletin No. 9, Chemical and Biological Survey of the Waters of Illinois. Urbana, 1912. (From the Survey.)
- Institution of Naval Architects, Transactions, vol. 55, pt. 2. 1913. London, 1913. (From the Institute.)
- John Crerar Library, Handbook, 1913. Chicago, 1913. (From the Library.)
- Lake Mohonk Conference of Friends of the Indian, Report of the 31st Annual Conference. Mohonk Lake, N. Y., 1913. (From the Conference.)
- Massachusetts State Board of Health, 44th Annual Report. Boston, 1913. (From the Board.)
- New Hampshire Public Service Commission, Report 1912, vol. 2. Concord, no date. (From the Commission.)
- New South Wales, Vital Statistics for 1912. Sydney, 1913. (From the Government Statistician.)
- New York State Public Service Commission for the First District. Annual Report 1912, vol. 1. New York, 1913. (From the Commission.)
- Ohio Department of Mines, Report of the Coal Mining Commission, 1913. Columbus, 1913. (From the Department.)
- Ontario Department of Agriculture: 34th Annual Report of the Ontario Agricultural and Experimental Union, 1912, and Annual Report of the Bureau of Industries, 1912. Toronto, 1913. (From the Department.)
- Pennsylvania Topographic and Geologic Survey Commission: Report for 1910-1912, and Report No. 6, Graphite Deposits of Pennsylvania, by Benjamin L. Miller. Harrisburg, 1912. (From the State Geologist.)
- Philadelphia Department of Public Works, Annual Report of the Department and Bureau of Water, 1912. Philadelphia, 1913. (From the Department.)
- Polytechnic Institute of Brooklyn, Catalogue of the College of Engineering, 1914-1915. Brooklyn, no date. (From the Institute.)
- R Istituto d' Incoraggiamento di Napoli, Atti, Serie Sesta, 1912. Napoli, 1913. (From the Istituto.)
- St. Louis & San Francisco Railroad Company, 17th Annual Report, 1913. St. Louis, no date. (From the Company.)
- Simeon North, First Official Pistol Maker of the United States: A Memoir, by S. N. D. North and Ralph H. North. Concord, N. H., 1913. (From R. H. North.)
- Southern Pacific Company, 29th Annual Report. New York, 1913. (From the Company.)
- Stephens Memorial Library, Brief Subject Catalogue, 1913. Philadelphia, 1913. (From the Librarian.)
- United States Library of Congress, Report 1913. Washington, D. C., 1913. (From the Library.)
- University of Chicago, Annual Register, 1912-1913. Chicago, 1913. (From the University.)
- Vassar College, 49th Annual Catalogue, 1913-1914. Poughkeepsie, N. Y., 1913. (From the College.)
- Vermont State Library: Vermont Insurance Report, 1912, and Bank Commissioner's Report, 1913. Montpelier, 1913. (From the Library.)
- Victoria Memorial Museum, Bulletin, No. 1. Ottawa, 1913. (From the Canada Geological Survey.)

Worcester Polytechnic Institute, 44th Annual Catalogue, 1913-1914. Worcester, Mass., 1913. (From the Institute.)

Yonkers Bureau of Water, 40th Annual Report, 1913. Yonkers, N. Y., 1913. (From the Bureau.)

PUBLICATIONS RECEIVED.

The Mechanical Engineer's Reference Book. A Hand-book of Tables, Formulas, and Methods for Engineers, Students, and Draftsmen, by Henry Harrison Suplee, B.Sc., M.E. 4th edition, revised and enlarged. 964 pages, illustrations, 12mo. Philadelphia, J. B. Lippincott Company, 1913. Price, \$5.

Le Chatelier, H.—Molécules, Atomes et Notations Chimiques. Mémoires de Guy-Lussac, Avogadro, Ampère, Dumas, Gaudin, Gerhardt. 116 pages, plate, 12mo. Paris, Armand Colin, 1913. Price, 1.20 francs.

Gautier, Henri.—L'air, l'Acide Carbonique et l'Eau. Mémoires de Dumas, Stas, Boussingault. 104 pages, plates, 12mo. Paris, Armand Colin, 1913. Price, 1.30 francs.

Industrial Organic Analysis for the Use of Technical and Analytical Chemists and Students, by Paul S. Arup, B.Sc., A.C.G.I., with a foreword by J. C. Irvine, D.Sc., Ph.D. 340 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son and Company, 1913. Price, \$2.25.

Quantitative Chemical Analysis, Adapted for use in the Laboratories of Colleges and Technical Institutes, by Frank Clowes, D.Sc., Lond., and J. Bernard Coleman, A.R.C.Sc., Dublin. Tenth edition. 577 pages, illustrations, 8vo. Philadelphia, P. Blackiston's Son and Company, 1914. Price, \$3.50.

Allen's Commercial Organic Analysis. A Treatise on the Properties, Modes of Assaying, and Proximate Analytical Examination of the Various Organic Chemicals and Products Employed in the Arts, Manufactures, Medicines, etc., with Concise Methods for the Detection and Estimation of their Impurities, Adulterations, and Products of Decomposition. Volume VIII: Enzymes, Proteins and Albuminoid Substances, Milk, and Milk Products, Meat and Meat Products, Hæmoglobin and Blood, Proteids, Fibroids, by the editors and the following contributors: E. F. Armstrong, S. B. Schryver, L. L. Van Slyke, Henry Leffmann, Cecil Revis, W. D. Richardson, J. A. Gardner, E. R. Bolton, G. A. Buckmaster, W. P. Dreaper, Jerome Alexander. Fourth edition, entirely rewritten, edited by W. A. Davis, B.Sc., A.C.G.I., and Samuel S. Sadtler, S.B. 696 pages, illustrations, 8vo. Philadelphia, P. Blackiston's Son and Company, 1913. Price, \$5.

Chemistry, Inorganic and Organic, with Experiments, by Charles London Bloxam. Tenth edition, rewritten and revised, by Arthur B. Bloxam, F.I.C., and S. Judd Lewis, D.Sc., F.I.C. 878 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1913. Price, \$5.50.

U. S. Geological Survey: Mineral Resources of the United States, Calendar Year 1912. Part II—Nonmetals. 1218 pages, illustrations, plates, maps, 8vo. Washington, Government Printing Office, 1913.

The Manufacture of Reinforced Concrete Poles, Piles and Pipe without the Use of Forms. Process of R. M. Jones. 27 pages, illustrations, plates, folio. Denver, Col., 1914.

Topographic and Geologic Survey of Pennsylvania: Report No. 6, Graphite Deposits of Pennsylvania, by Benjamin L. Miller, Professor of Geology in Lehigh University. 147 pages, illustrations, maps, 8vo. Harrisburg, State Printer, 1912.

La Mesure de l'Intensité des Courants Faibles et de Haute Fréquence par Béla Gáti. Extrait de L'Industrie Électrique No. 525, 10 November, 1913, p. 498. 4 pages, illustrations, quarto. Paris, 1913.

Mellon Institute of Industrial Research and School of Specific Industries: Smoke Investigation, Bulletin No. 5. The Meteorological Aspect of the Smoke Problem, by Herbert H. Kimball, Ph.D., Professor of Meteorology, United States Weather Bureau. 51 pages, map, 8vo. Pittsburgh, Pa., University of Pittsburgh, 1913.

Canada Department of Mines: The Production of Coal and Coke in Canada during the Calendar Year 1912, by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 40 pages, 8vo. Ottawa, Government Printing Bureau, 1913.

U. S. Bureau of Mines: Bulletin 66. Tests of Permissible Explosives, by Clarence Hall and Spencer P. Howell. 313 pages, illustrations, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, November, 1913. 23 pages, 8vo. Technical Paper 50—Metallurgical Coke, by A. W. Belden. 48 pages, illustrations, map, 8vo. Technical Paper 56—Notes on the Prevention of Dust and Gas Explosions in Coal Mines, by George S. Rice. 24 pages, 8vo. Washington, Government Printing Office, 1913-1914.

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Color Changes in Colloidal Gold. S. H. LONG. (*Proc. Univ. Durham Phil. Soc.*, v, 113.)—Electrical migration and other tests were made on red, blue, and purple colloidal gold solutions prepared by electrical disintegration by means of a high-frequency alternating arc. The results show that the red colloid moves to the cathode and is probably associated with hydroxyl ions; the particles are very small. The blue colloid moves to the anode and is probably associated with hydrogen ions. The red colloid is less stable than the blue, into which it is converted by the action of an electrolyte or of an electric field. The purple colloid is a mixture of the red and blue forms in variable proportions.

CURRENT TOPICS

Record Production of Portland Cement in 1913.—According to returns received by the United States Geological Survey up to January 12, 1914, it is estimated by Ernest F. Burchard that the quantity of Portland cement manufactured in the United States in 1913 was approximately 92,406,000 barrels, compared with 82,438,096 barrels in 1912, an increase of about 9,967,900 barrels, or 12 per cent. The estimated shipments of Portland cement during 1913 were 88,853,000 barrels, compared with 85,012,556 barrels in 1912, an increase of about 3,840,400 barrels, or 4.5 per cent. On account of a large surplus of production over shipments stocks of cement at the mills apparently increased more than 45 per cent., or from 7,811,329 barrels in 1912 to 11,375,000 barrels at the close of 1913. In 1913 the relations between production and shipments were the reverse of those for 1912, when shipments exceeded production. It may be necessary to revise considerably the estimates of stocks, but it is believed that these figures for production and shipments are very close to those that will be shown by complete returns from all producers.

Although few definite statements as to selling prices are at hand, it is evident that the average value per barrel was appreciably higher than in 1913. Increases of 10 to 25 cents a barrel are reported from several plants in the Central and Eastern States, but there were slight decreases reported from a few plants in the Rocky Mountain district.

Two new plants, both in Washington, were added to the list of producers during 1913.

“Coalescence” in Metallic Lead. H. BANCKE (*Int. Zeits. Metallg.*, ii, 243.)—The growth of certain crystals at the expense of others, or “coalescence,” in the case of lead has been ascribed by Rosenhain to an electrolytic effect wherein the eutectic acts as an electrolyte. Bancke shows that coalescence of rolled lead takes place on immersion in dilute acids, such as 5 per cent. acetic acid or 5 per cent. alcoholic nitric acid, more rapidly than was stated by Ewing and Rosenhain. The coalescence is sometimes energetic, with formation of large crystals, the metal becoming brittle. It has not been found possible by this “etching” method to control the extent of coalescence. With lead-foil the action is very rapid, and lead tubes often show vigorous coalescence. Coalescence precedes and makes possible rapid corrosion of lead. The examination of corroded lead showed that the unattacked portions consisted of normal-sized grains.

Photochemical Properties of Tungstic Acid. A. F. WASILIEFF. (*J. Russ. Phys. Chem. Soc.*, xliv, 819.)—In the presence of various reducing agents, *e.g.* cellulose, and under the influence of sunlight, tungstic acid undergoes change with formation of a blue color. According to Sabanéef, the action of hydrochloric acid on sodium tungstate gives, not colloidal tungstic acid, as Graham said, but sodium meta-tungstate: $4\text{Na}_2\text{WO}_4 + 6\text{HCl} = \text{Na}_2\text{O}_4\text{WO}_3 + 6\text{NaCl} + 3\text{H}_2\text{O}$. The author's investigations on the influence of sunlight in presence of dextrose on the initial product of this reaction indicates that this product, which is sensitive to light, is probably not sodium meta-tungstate. The initial product undergoes change into one which shows no photochemical properties at a velocity corresponding with the equation of a reaction of the first order; a rise of temperature causes the reverse change.

The International Engineering Congress of 1915.—Under the auspices of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers, there will be convened at the Panama-Pacific International Exposition, in 1915, an International Engineering Congress.

Engineers in all parts of the world have signified their intention of attending, and the delegation from Great Britain promises to be large in point of numbers and great in distinction.

The presidents and secretaries of the five organizations above named, together with eighteen other members, constitute the official body which will assemble and conduct the Congress. Colonel George W. Goethals, Chief Engineer of the Isthmian Canal Committee, has consented to act as Honorary President of the Congress, and will be in attendance in San Francisco when the celebration is held commemorating the completion of the greatest engineering achievement in all history.

The week of September 20–25, 1915, will be the time of the sessions of the International Congress, and the proceedings of the meetings will be preserved in permanent book form. These volumes will contain the papers contributed to the Congress by eminent engineers, and will embrace in their scope every line of engineering activity, giving the latest word of authority in the field of engineering.

The executive offices of the Congress are in the Foxcroft Building, San Francisco, Cal., where the following officers of the committee are located: W. F. Durand, chairman; W. A. Cattell, secretary-treasurer; E. J. Dupuy, executive secretary.

A tentative schedule of general sessions has been formulated, and the following sections will be considered: 1, The Panama Canal; 2, Waterways and Irrigation; 3, Railways; 4, Municipal Engineering; 5, Materials of Engineering Construction; 6, Mechanical En-

gineering; 7, Electrical Engineering; 8, Mining Engineering; 9, Naval Architecture and Marine Engineering; 10, Military Engineering; 11, Miscellaneous.

Each of these sections will hold independent sessions during the Congress. Such joint sessions as may be deemed advisable will also be called. On account of the convention of the International Congress of Electrical Engineers just prior to the International Engineering Congress, the activity of the latter in the field of electrical engineering assigned to Section 7 will be limited to consideration of the points of contact between electrical engineering and other engineering phenomena and work.

Development of Photographic Images. W. H. CALDWELL. (*Eng. Pat.* 14,744, 1911.)—This invention provides a process of developing exposed photographic films in such a way that the silver halide dissolved by the developer shall not be reduced instantaneously, as in the known developers, but shall have time to travel to all the "unit portions" of silver halide which have been affected by light, and shall be reduced to silver in contact with each of such "unit portions," thus effecting much better development in the case of over-exposed images. For this purpose the proposed developer is an aromatic hydrazine in conjunction with an alkali bisulphite in solutions acid to litmus; for example, equal molecular proportions of phenylhydrazine and sodium bisulphite may be used. As phenylhydrazine has an irritant action on the skin, it may be replaced by *o*- or *p*-tolylhydrazine, or *o*- or *p*-bromophenylhydrazine. By regulating the strength of the developer any desired gradation may be produced. This mode of development may be applied to the films or surfaces described in English patent 1689 of 1908 to produce results of the correct scale of density, however prolonged the exposure may have been.

Use of Liquid Nitrogen for Producing Temperatures down to -211°C . G. CLAUDE. (*Comptes Rendus*, clvii, 277.)—The ease is demonstrated with which, in the absence of liquid hydrogen, it is possible to attain in a few minutes the solidification temperature of nitrogen, viz., -210°C . The principle adopted is that when a current of air is rapidly passed through a liquefied gas, this is cooled below its normal ebullition point. The process employed is more convenient, rapid, and permits the use of smaller quantities of liquid nitrogen than evaporation *in vacuo*. The liquid nitrogen is contained in a D'Arsonval-Dewar flask into which the extremity of a copper worm dips. The worm is cooled in another vessel by liquid nitrogen and traversed by a current of hydrogen, which is bubbled through the liquid, thereby producing rapid cooling, *e.g.*, -200°C . after two minutes, -206°C . after six, and -210°C . after twelve minutes. The experimental conditions are given, which are simple and allow of working with an open vessel.

Paper-Making Materials in Java. H. G. HAVIK (*Papier Fabrikant*, x, 859.)—*Bamboo*.—The bamboo is very abundant in Java, the principal species being *apus* and *andong*. For a mill producing 1500 tons of cellulose from three-year stems an area of 420 hectares (1040 acres) would have to be planted. In the large towns bamboo is worth 10 to 20 gulden (\$4.25 to \$8.50) per ton of air dry weight. From the *apus* bamboo there is obtained 50 per cent. of half-stuff on digestion with 19 per cent. of sodium hydroxide, calculated, on dry weight, for six hours under three atmospheres pressure. From the *andong* bamboo, with 15 per cent. of soda under a pressure of $4\frac{1}{2}$ atmospheres for eight hours, a yield of 49 per cent. of pulp was obtained. The pulps were not suitable for bleaching, but gave excellent unbleached paper; the length of the fibres ranges from 1.6 to 4.6 mm.; average, 2.7 and 3.0 mm.

Alang-alang Grass.—This grows in great abundance and spreads very rapidly, attaining a height of 1.5 metres in a period of five weeks. This yields only 29.3 per cent. of cellulose on digestion with 9 per cent. sodium hydroxide for five hours under five atmospheres pressure; the pulp was difficult to bleach. This is at variance with Cross and Bevan's results, who obtained 55 per cent. of a cellulose which bleached easily. Length of fibre, 0.5 to 2.5 mm.; average, 0.8 mm.

Maize Straw is obtained in Java, often as a second crop after rice; more is produced than is needed. After cutting out the knots, the straw was digested with 21 per cent. of soda under three to four atmospheres for five hours; the yield was 22 to 23.2 per cent. of pulp not easily bleached; the paper made was of excellent strength. Length of fibre, 1 to 3 mm.; average, 1.5 mm.

Albizzia Moluccana.—Sheets of paper were prepared from the cellulose pulp of this wood, and from the mechanical pulp, blending them with other Javan fibres. From the results it is concluded that *Albizzia* wood is a useful and valuable paper-making material.

Water-Gas Tar for Killing Weeds. ANON. (*J. Gas Lighting*, cix, 332.)—Experiments made by the Conestoga Traction Company, of Lancaster, Pa., upon 160 miles of railroad track, show that a sprinkling of water-gas tar is an effective weed killer, and prevents the growth of fresh weeds. About 3000 gallons of tar were sprinkled on each mile of track.

The F-Rays do not Exist. ANON. (*Sci. Amer.*, cix, No. 15, 279.)—The discovery of F-rays recently announced has been contradicted. According to very precise and detailed information published by the *Eclair*, it appears that the results obtained are not at all conclusive. The F-rays appear to be an illusion similar to that to which the scientific world was a victim when the physicist Blondlot, Professor at the Faculty of Nancy, announced the discovery of the N-rays.

Peat for Power Purposes. H. V. PEGG. (*Inst. Mech. Eng.*, July 31, 1912.)—A gas producer at Portadown supplying about 250 British horsepower has given good results when working with peat which has not been subjected to any preliminary treatment for reducing its moisture, which varied roughly from 18 to 70 per cent., according to weather conditions. The only difficulty experienced was in cleaning the gas from tar; but this was overcome by the use of an ample water spray using about 7 gallons of water per British horsepower per hour. The engine valves required cleaning about once a week, and the whole plant was cleaned at the same time, though it was possible to run the producer for three weeks. The tar does not find a ready sale, owing to the pyroligneous odor, which can not be removed either from the tar or the oils distilled therefrom. A saving of over 50 per cent. was effected in the fuel bill by running the factory on peat instead of coal, consuming about 50 tons of peat per week. From peat containing 44.6 per cent. of carbon, 5.42 per cent. of hydrogen, and 18.98 per cent. of moisture a gas was obtained of the following composition: carbon dioxide, 10.6 per cent.; carbon monoxide, 21.0; hydrogen, 13.0; methane, 3.7; total combustible, 37.7 per cent.; calorific value, 144.0 British thermal units.

Synthetic Formation of Coal. BERGIUS. (*J. Gasbeleucht.*, liv, 748.)—By means of a specially-constructed bomb, bored out of a block of steel, and heated in an electrical furnace, carbon and water were found to react at about 350° C., producing carbon dioxide and hydrogen in the proportions of 1 : 2 by volume. Peat and cellulose, heated in the same apparatus to temperatures of 250° to 340° C., produced a substance which on further continued heating at 340° C. yielded a material resembling natural bituminous coal both in appearance and composition. As in the natural formation of coal, gases were evolved, chiefly carbon dioxide and methane. The longer the duration of the experiment, and the higher the temperature, the higher was the percentage of carbon and the lower that of oxygen in the resulting coal. The speed of reaction increases with the temperature; 64 hours at 310° C. were equivalent to 8 hours at 340° C., and from this change in speed of reaction it is calculated that, at the ordinary temperature, the formation of natural coal must have required about eight million years.

Iodine in Java. ANON. (*Rev. Scient. Rep.*, xxv, 352.)—Iodine is derived in considerable quantity from the saline constituents of certain mineral springs in Java, where it occurs chiefly as magnesium iodide, and is precipitated from them by means of copper sulphate. One Javan spring is said to yield as much as 12 centigrammes of iodine from each litre of water. The output of iodine from the Dutch East Indies amounts to about 30 tons per annum. It might be much more if more capital were employed in the undertaking.

Copra and Margarine and the Rise in the Price of Cocoanut Oil. ANON. (*Times*, Oct. 20, 1913.)—The comparative scarcity of copra in view of the increasing demand for margarine has caused a great rise in its price. In every quarter where copra is bought and sold, and even in Japan, despite the popularity of the Soya bean, plants for the manufacture of cocoanut oil are being rapidly erected. To extract the oil, the copra is milled, the resultant meal steamed and formed into cakes, and the oil squeezed out by hydraulic pressure. This is done, not upon the spot, but by a limited number of refiners in Europe and America. Cocoanut oil has long been used in the manufacture of free lathering soaps, called "washers" in the trade, as well as for what are termed "cold process" and "marine" soaps. It also is used for the manufacture of candles and night lights. On the other hand, it was never used for edible purposes in civilized countries, owing to its insinuating cocoanut taste and the speed with which it becomes rancid. These faults have been eliminated by chemical means, and cocoanut oil finds its way to the table in many forms. Cocoanut lard is now manufactured on a very large scale, and the oil has taken the place of animal fats in the manufacture of margarine. In its most highly refined form, blended with milk, it appears on the Continent as actual butter. Since the methods of purification were discovered the price has risen from £12 per ton to £48. The kernels are the staple food of the people where the nuts grow, and, as their needs must be satisfied before there is any margin for export, there does not appear any likelihood of overproduction.

A New Type of Kinematograph Camera. K. PROSZYNSKI. (*Phot. Journ.*, liii, 99.)—The article deals first with the principles governing the production of kinematograph effects, chiefly with regard to the elimination of flicker, and includes a detailed description, with illustrations, of a new type of kinematograph camera, which may be used like a hand camera, without any supporting stand. To obviate any effect of vibration, the front of the camera contains a powerful gyrostatic wheel, thereby keeping the camera very steady in any desired position. The motive power for driving the film is obtained from a set of cylinders containing compressed air, which are fitted in the back of the camera. These supply power to an efficient air motor which runs the film and shutter mechanism. Excellent results were demonstrated at the time the paper was read before the Royal Photographic Society.

Continuity. O. LODGE. (*Chem. News*, cviii, 127.)—The author urges a belief in ultimate continuity as essential to science; regards scientific concentration as an inadequate basis for philosophic generalization; believes that obscure phenomena may be expressed simply if properly faced; and points out that the nonappearance of anything perfectly uniform and omnipresent is only what should be expected, and is no argument against its real substantial existence.

Physico-Chemical Studies of Photographic Developers: Quinol as an Inductor. N. SCHILOW and E. TIMTSCHENKO. (*Z. Elektrochem.*, xix, 816.)—Sodium arsenite has an effect on the atmospheric oxidation of quinol solutions very similar to that of sodium sulphite; during the earlier stages of the oxidation the process is less rapid than without arsenite, but in the later stages the total amount of oxygen absorbed is greater than when arsenite is absent. Since sodium arsenite is not likely to form complex compounds with quinol, it is probable that it acts merely as a protective agent for the quinol. The oxygen is distributed between the quinol and the arsenite in the rates of 1 : 1.2, as compared with 1 : 1, which is the ratio for an ideal "acceptor" of oxygen. Analogous experiments with the aid of hydroxylamine and hydrazine as "acceptors" gave somewhat similar results, but it is considered probable that series of addition products are formed in these cases. The retarding and "regularizing" effect of hydroxylamine is so marked that its use in the preparation of "stand" developers is suggested.

Chromium Red Glaze. C. E. RAMSDEN. (*Trans. Eng. Ceram. Soc.*, xii, 239.)—This communication deals with the best glaze, maturing at the desired temperature, which will develop and display the tint imparted by the stain. The presence of lime is essential to prevent decomposition of the stain by the glaze. Though lime in excess of 0.2 CaO is unnecessary its content should never drop below 0.1 CaO. The basic oxides should consist largely of lead oxide, which helps to form a translucent yellow glass imparting a blood-red tint to the crimson stain. A small amount of alkali oxide is useful to produce translucency, but the proportion $R_2O : RO$ should not be greater than 1 : 4; the stain is soluble in alkaline silicate and borates; both potassa and soda impart a lilac or violet tint. Alumina destroys the crimson color if in greater proportion than 0.3 Al_2O_3 . If not fritted with the glaze mixture, as much as 0.5 Al_2O_3 may be introduced to obtain a pink; any excess over 0.1 Al_2O_3 diminishes the red tint. Boric acid imparts translucency, while it has only a slight tendency to communicate a lilac shade; the most favorable quantity appears to be equimolecular with the lime content, the greater the lime the more boric acid being permissible without attacking the stain. Zinc oxide brightens the surface, and may be introduced up to half the molecular content of lime. More than 0.3 BaO destroys the color; 0.5 SrO impairs the tint; magnesia should be excluded entirely. Silica may vary from 1.5 to 2 equivalents, according to the time and temperature of firing; glazes rich in silica tend to acquire a green tint. The author arranges oxides into two classes, according to their influence on the crimson glaze at cone 0.5 and in the order of their apparent effect on the color, beginning with that which has the greatest effect: *Favorable*—CaO, Bi_2O_3 , PbO, B_2O_3 , SiO_2 , Na_2O , K_2O , Al_2O_3 . *Injurious*— Sb_2O_3 , MgO, P_2O_5 , SrO, ZnO, BaO, and Al_2O_3 .

Approximate Melting-Points of Some Commercial Copper Alloys. H. W. GILBERT and A. B. NORTON. (*Amer. Inst. of Metals*, Oct., 1913.)—The alloys (except manganese bronze, in which case the previously made alloy was melted) were all made by melting together the constituents in the carborundum crucible in which the determinations were made. Heating and cooling curves were plotted, and the temperature at which solidification began or fusion was completed was taken as the melting-point. The composition given is that aimed at, and actual analysis, in all cases where it was made, showed that this was very nearly attained. The results are as follows:—

Alloy	Percentage composition				Melting-point, °C.
	Cu.	Zn.	Sn.	Pb.	
Gun-metal.....	88	2	10	—	995
Leaded gun-metal.....	85½	2	9½	3	980
Red brass.....	85	5	5	5	970
Low-grade red brass.....	82	10	3	5	980
Leaded bronze.....	80	—	10	10	945
Bronze with zinc.....	85	5	10	—	980
Cast yellow brass.....	67	31	—	2	895
Naval brass.....	61½	37	1½	—	855
Manganese bronze.....	{ 56 Fe 1.5	{ 41 Al 0.45	{ 0.9 Mn 0.15	{ —	870

Experiments on Rails. ANON. (*Amer. Mech.*, xxxvii, 3, 125.)—Just at present many experiments are being made to produce a rail that will be more resistant to wear than those now in use. According to the United States Geological Survey, over 150,000 tons of nickel and nickel-chromium steel rails were rolled in 1910, besides about 80,000 tons of chromium, manganese, vanadium, and other similar steels. Most of the experimenting, however, was done on titanium steels, 250,000 long tons of which were rolled. There need be no titanium left in the steel: its value lies in its absorptive power for nitrogen, oxygen, and other impurities.

Calcium Cyanamide Production. ANON. (*Oil, Paint and Drug Reporter*, July 29, 1912.)—The American Cyanamide Company has contracted for the extension of its calcium cyanamide plant at Niagara Falls, Ont., in addition to new machinery, at an approximate cost of \$500,000, which will more than double the present capacity of the factory. This company uses the Frank and Caro process. Now the company uses 6000 electric horsepower. It began the manufacture of cyanamide in January, 1910; and during that year exported to the United States product valued at \$211,202. In 1911 the value of the cyanamide shipped to the United States was \$338,774, and, judging from exports during the present year, the increase will be much greater.

Progress of the Fixation of Nitrogen Process in Scandinavia. (*Times, Eng. Suppl.*, Oct. 15, 1913.)—The successful commercial development of the process for oxidizing ammonia to nitric acid by means of the catalytic action of platinum is described. The carbide works at Odda, Norway, when operations were started, comprised ten furnaces, each with a capacity of seven to eight tons of carbide per 24 hours. Ten more furnaces, each of 16 to 18 tons capacity, have recently been added. The temperature is maintained at 5720° F. (3160°C.), the electrodes of the older furnaces taking 1400 kilowatts and those of the newer ones 3500 kilowatts. It is stated that the radiation of heat from the new furnaces is less than from a steam boiler. The hot gases from the furnaces are used in the lime-kilns instead of producer gas. The annual output, 32,000 tons up to recently, is now 80,000 tons of carbide. Most of this carbide passes direct to the calcium cyanamide works of an associated company, which at the present time has an annual output of 80,000 tons, the number of furnaces having been increased nearly seven-fold since the works started four years ago. The nitrogen used is prepared by the Linde process, 100 tons of air being liquefied daily. The furnaces have a capacity of one ton each; the nitrogen is supplied through valves in the side, and a current at 60 to 75 volts through an electrode in the centre. After about 24 hours at 1650° F. (900° C.) the carbide is converted into cyanamide, the product containing 20 per cent. of nitrogen. In addition to these developments a company formed to acquire the rights of the Ostwald process (except in Westphalia and Rhineland) is erecting new works for the manufacture of carbide and cyanamide (and nitric acid) at Aura, Norway, with an estimated output of 200,000 tons of calcium cyanamide, and has acquired waterfalls at other places in Norway and also in Iceland, capable of furnishing power for an annual output of nearly 2,000,000 tons of calcium cyanamide. Works are to be erected at Dagenham on the Thames, at Trafford Park, Manchester, in Scotland, and in Ireland for producing from calcium cyanamide 12,000, 12,000, 9000, and 3000 tons of nitric acid respectively. In the event of the supply of calcium cyanamide being curtailed or stopped, it will be possible to use the ammoniacal liquors from coke ovens, blast furnaces, residual recovery plant, and gas works as sources of ammonia.

Spotting-Out and Silver Plating. C. F. BURGESS and L. T. RICHARDSON. (*Amer. Inst. of Metals*, Oct., 1913.)—The gradual formation of spots on plated articles, known as "spotting-out," is considered to be probably due to galvanic action. The surfaces of brass castings often contain minute pits which frequently enclose small quantities of electrolyte (cyanides), which form an electrical contact between the brass and silver. Since the electrolyte is not necessarily consumed in the process, but may serve simply as a conducting medium, it is possible for a very small amount to cause extensive corrosion.

Speed Regulation of Induction Motors. F. W. MEYER. (*Elektrotechn. Zeitschr.*, xxxiv, 903.)—This is a development of the theory of a machine for simultaneously regulating the speed and power factor of induction motors. The machine considered has an armature similar to that of a rotary converter, and is connected to the supply mains at the slip-ring end through the medium of a variable-ratio transformer, while at the commutator end it is connected to the slip-rings of the induction motor. The stator carries a light three-phase winding which is closed on an external adjustable resistance. The armature is not mechanically connected to any other machine. The torque required to overcome the friction and other rotational losses is furnished by the agency of the currents in the stationary secondary circuits, as in an ordinary induction motor, and the speed can be controlled by the rheostats in those circuits. The same control determines the frequency of the electromotive forces at the commutator, which are injected into the rotor-circuits of the main motor, and so fixes the speed of the latter. The correct relation between the magnitude and frequency of these electromotive forces which is necessary to produce a given speed and power-factor is obtained by simultaneous adjustment of the stator rheostat and the variable-ratio transformer which connects the armature to the supply.

Transformations of the Active Deposit of Thorium. E. MARSDEN and C. G. DARWIN. (*Proc. Roy. Soc.*, A87, 17.)—Experiments undertaken to discover the genetic arrangement of the various products of the active deposit of thorium, especially the nature of the transformations which take place in the product or products generally included under the name thorium C, have shown that of the atoms of thorium C, 35 per cent. emit α -particles of range 4.8 cm. and are converted into atoms of thorium D, while the remaining 65 per cent. emit β -particles and disintegrate into atoms of a very short-lived α -ray product, thorium C₂, range 8.6 cm. The transformations are regarded as of unusual interest, as the case furnishes undoubted evidence of atoms of a single kind of matter having two distinct modes of disintegration.

Tungsten Lamps Taking 0.5 Watt per Candle-Power. ANON. (*Elect. Rev. and West. Electn.*, lxiii, 156.)—The General Electric Company announces a new type of tungsten lamp operating at a specific consumption of only 0.5 watt per candle-power. Specially-shaped tungsten filaments in the form of loops of closely-wound spirals are used, and the bulb is filled with inert nitrogen at a pressure of about one atmosphere. It is anticipated that lamps of high candle-power taking six ampères and over will first be introduced, and that their higher efficiency will enable them to be used in fields not hitherto covered by incandescent lamps.

Einstein's Stationary Gravitation Field. P. EHRENFEST. (*Konink. Akad. Wetensch Amsterdam. Proc.*, xv, 1187.)—Discusses the hypothesis of equivalence on which Einstein bases his attempt at a theory of gravitation, and which requires a curvature of the rays of light in a field of attraction. The problem is put thus: Let a laboratory L, with the observers in it, have some accelerated motion with regard to a system of coördinate x, y, z , which is not accelerated. Let it, for example, move parallel to the z -axis with some positive acceleration. Then the observers will find that all the inert masses which are at rest with regard to the laboratory exert a pressure on the bodies which are in contact with their bottom sides. There are two ways for these observers to explain this pressure: (1) Our laboratory has an acceleration upwards, hence all inert masses press on the bodies under them; (2) our laboratory is at rest; but a field of force acts in it which pulls the masses down. Observations on the course of the rays of light seem to make it possible to decide between the ways (1) and (2), for, with regard to the system of coördinate x, y , and z , the light travels rectilinearly, but with regard to the accelerated laboratory *curvilinearly*. The conclusion is reached that all statical fields of attraction, except those of a very particular class, are in contradiction with Einstein's hypothesis of equivalence. For example, the statical field due to several centres of attraction which are stationary with respect to each other is not compatible with the hypothesis of equivalence.

Hardened Metal. ANON. (*Amer. Mach.*, xxxix, No. 16, 662.)—According to a French contemporary, a metal can be regarded as hardened if it is possible to soften it by annealing. The extent of the hardening may be expressed numerically by the ratio obtained by dividing the hardness number of the metal by its hardness number when fully annealed. Such hardness ratios were obtained for silver, aluminum, aluminum bronze, and copper bronze, and were found to express satisfactorily the extent of hammer hardening. The ratios were obtained usually with a ball 0.12 inch in diameter under a pressure of 66 pounds. The hardness ratios were about the same when 2200 pounds pressure was applied. By using the lesser pressure the hardness of bismuth was determined as 4.6 to 4.8 and of antimony as 58.42.

Electrification by X-Rays. C. G. BÉDREAG. (*Compt. Rendus*, clvii, 39.)—Experiments were made on the electrification of electrodes of brass and silver exposed at low pressures to X-rays. As the pressure is decreased below about 10^{-3} mm. mercury the electrodes become charged with an increasing positive charge, which is further increased when the electrodes are placed in a magnetic field. At atmospheric pressure the particular electrodes become negatively charged.

New Fuel. ANON. (*Amer. Mach.*, xxxix, No. 20, 834.)—A new fuel for automobiles and internal-combustion engines is announced, in British papers, under the name of Economin. This has for its base 80 per cent. of kerosene, the remainder being chemicals which form an emulsion. Then the mixture is distilled and gives a fuel which is cheaper than gasoline, in England at least, and which gives more power from the same motor. It is further claimed to give practically perfect combustion, so that there is almost no carbon deposit in the cylinders, to be almost odorless, and to make an easy-starting motor. It can be used with the same carburettor adjustment as gasoline. The fuel is not yet on the market, but a plant to turn out 20,000,000 gallons per year is under construction.

The Baldwin Locomotive Works. ANON. (*Amer. Mach.*, xxxix, No. 16, 652.)—This locomotive works, after 82 years of continuous operation, has produced 40,000 locomotives. The first was completed in 1832, when the industry was in its infancy. The five thousandth locomotive was built in 1850, eighteen years later, during which period two important types of freight locomotives, the "Mogul" and "Consolidation," were introduced and widely adopted. From 1889 to 1902, when locomotive number 20,000 was built, compound locomotives came into extensive use; and trailing wheels, allowing increased boiler capacity without imposing excessive loads on the driving wheels, were introduced. The average annual production for the five years from 1902 to 1907 was approximately 2000 locomotives, and locomotive No. 30,000 was built in 1907. During this period occurred the introduction of the Mallet articulated compound locomotive and the adoption of the Walschaerts valve motion. This period has been marked by the extensive use of superheaters, brick-arches, and other devices; and the mechanical stoker is another accessory developed during the past few years.

Nitrogen in Iron. W. HERWIG. (*Stahl und Eisen*, xxxiii, 1721.)—The gas contained in the blisters formed on steel plates during rolling and annealing was found to consist chiefly of nitrogen. The gases evolved during the solidification of iron immediately after tapping from the blast furnace include large quantities of hydrogen and carbon monoxide, white iron containing more hydrogen, and hot-blast gray iron more carbon monoxide. The nitrogen in steel turnings was reduced by heating in a current of hydrogen from 0.022 to 0.006 per cent., and, although it was not increased by heating in a current of nitrogen, yet from a mixture of nitrogen and hydrogen in equal proportions a steel was obtained, in one case, with as much as 0.052 per cent. nitrogen. The author considered that a similar action takes place in the converter. A steel containing 0.04 per cent. nitrogen, when tested, broke without elongation, but was improved by prolonged annealing.

Aluminum Bronze Containing Boron. ANON. (*Brass World*, ix, No. 12, 441.)—Edward D. Gleason, of New York, has recently patented a process for the use of boron in aluminum bronze. It is claimed that this alloy does not tarnish as readily as bronze without boron, and has superior physical properties. It is made in this way: Aluminum is fused in a crucible under a layer of a mixture of three parts fluorspar and 1 part of boric acid. A high heat is used, so that boron fluoride forms, which reacts on the aluminum and boron is reduced. This reduced boron is absorbed by the aluminum, forming an alloy. This alloy is used in the proportion of 10 parts of alloy to 90 parts of copper for making an aluminum bronze. The alloying is effected under a layer of charcoal and black oxide of manganese.

Removing Lead from Water. P. SCHMIDT. (*Chem. Zentr.*, ii, 1258.)—The lead contained in tap water is present as hydroxide or basic carbonate in the form of a suspension or colloidal solution. On standing for a few days in tall cylinders the upper layers of the water are found to be richer in lead. In the case of water which has been boiled for a long time, the lower layers become richer in lead on standing. On the dialysis of water containing lead, no lead can be found in the outer water even in presence of excess of carbon dioxide. In accord with these facts showing that lead is present in the form of colloidal solution, it has been found that the lead can be completely removed by passing the water through a Berkefield filter or through a rapid filter of porous porcelain.

Influence of Drawing on the Properties of Metallurgical Products. L. GUILLET. (*Rev. de Métallurgie*, x, 769.)—This paper refers to the effect of cold work on the mechanical properties and the resistance of metals and alloys to corrosion. Drawing greatly increases the elastic limit and decreases the resilience. Elongation is diminished to a greater extent than the contraction. Experiments have been made on the resistance of aluminum and some of its alloys, to corrosion in water and in different saline solutions of various strengths. Although in a great many cases the cold worked product is attacked to a greater degree than the annealed product, this is by no means a general law. The action appears to be a function of the alloy and the acting reagent.

Aluminum Cooking Utensils. ANON. (*The Metal Industry*, ii, No. 12, 510.)—Prof. John Glaister, of Glasgow University, tested aluminum cooking utensils to ascertain if food was in any way injured by being prepared in them. The only substances that dissolved any of the metal were oranges, lemons, Brussels sprouts, and tomatoes, but even in these cases the quantity was so small as to be absolutely harmless.

Gripping Power of Portland Cement. H. LUFTSCHITZ. (*Tonnind. Zeit.*, xxxvii, 1491.)—The setting of Portland cement is assumed to be due to the formation of a gel, which ultimately hardens to a lime-aluminate-silicate mass and forms a close-fitting network around any embedded inert material. With concrete, such a network surrounding angular gravel or sand would be stronger than one enclosing rounded grains, and the strength attained with washed sand would be greater than unwashed, since, in the latter case, the intervening layer of soft clay prevents the surrounding network from directly gripping the grains of sand. Similarly, with ferroconcrete, rust is detrimental as preventing close contact between the iron and the surrounding gel.

Scandium in American Wolframite. H. S. LUKENS. (*J. Amer. Chem. Soc.*, xxxv, 1470.)—Meyer has shown that wolframite residues from Zinnwald contained sufficient scandium to make them a productive source of this element. Following Meyer's methods, the author has isolated pure scandium oxide from American wolframite residues from Colorado. From 3.2 kilos. of the residues, about 1.6 grammes of crude scandium oxide were obtained.



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PETROLEUM AND ITS DERIVATIVES.*

DAVID T. DAY, Ph.D.,

In Charge of Petroleum, Division of Mineral Resources, Department of Interior.
U. S. Geological Survey, Washington, D. C.
Member of the Institute.

It will be the purpose of this lecture, first, to familiarize you with such phases of the petroleum industry as may now seem obscure. Then, with a clearer conception of these fundamental matters, we can note how in these later years we are rapidly going further and actually varying the products obtainable from oil as it comes from its reservoirs deep in the earth. This will also suggest lines of investigation by which petroleum products may be transformed into the essentials of life should agricultural products fail.

Research.—Those who are simply interested broadly in petroleum will, I trust, take away from this lecture the conviction that petroleum can be manipulated in many novel ways, that it can at least be made to yield a vast number of useful products. Finally, my own faith permits me to offer you the hope that coal, sawdust, or other low-grade carbonaceous material may be converted into our most essential products by change first into petroleum—this complicated mother substance to which we are surely to look in the future for many of our supplies—and you will not be disappointed.

* Presented at the stated meeting held Wednesday, December 17, 1913.

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To those of you who are concerned with petroleum investigation I wish to appeal for coöperation in bringing these developments to pass. The time is propitious for organization in petroleum research.

Origin.—The most mysterious problem in regard to petroleum is that of its origin. This is also the problem of least immediate importance to the practical development of the subject.

The reason we actually know so little about this question is because one can count on the fingers of one hand the actual experimental investigations which have been carried on to determine the origin of petroleum, while no one could state off-hand the number of learned men who have occupied volumes with ingenious theories in the hope of settling this question by the speculative method.

There are a few scientific workers who firmly believe that the source of petroleum has been absolutely settled. They go further and state the steps by which one process after another has transformed the original material into petroleum as we find it.

The rest of the scientific world is in a more fortunate condition of doubt—fortunate because in this doubt it is necessary to experiment, and to experiment is to add to our store of knowledge concerning petroleum itself.

Two reasons make the study of the origin of petroleum really worth while: First, we want to know whether the sources of supply have been sufficiently great to predict vastly greater amounts of petroleum in the earth than have yet been discovered. Second, we wish to know whether materials exist for furnishing more petroleum, or whether the ancient stores are all we may ever draw upon.

Petroleum is spoken of as “organic” and “inorganic” by the partisans of the different theories of origin.

By “organic” they seem to mean *derived from material once the product of life processes*, such as plants and animals. No one will doubt that petroleum as it exists is an inorganic mineral substance, because the processes by which petroleum has been formed, no matter from what sources, are evidently inorganic, and no one would confuse the oil which we call petroleum with the oils obtained by organic processes, such as the oils of animals and plants.

The theories advanced by the inorganic and by the organic

groups of speculators concerning the origin of oil are plausible and interesting.

The Inorganic Idea.—The general idea of inorganic origin calls attention to the earth as once a mass too hot for any element to exist in combination with another.

Accepting this idea, we know, by the experience with the electric furnace, that when the earth cooled sufficiently for elementary bodies to combine, compounds of metals with carbon,—*i.e.*, “carbides,”—are among the first to form. They can exist at higher temperatures than other compounds.

As the earth cooled still further, other combinations were possible, such as hydrogen with oxygen.

We can think, then, of a primitive “carbide earth,” and, as this cooled, water existing as steam in the atmosphere gradually attacked the carbides with the formation of hydrocarbons, including petroleum, which escaped into the air. After such action the earth consisted of the oxidized crust, and a carbide interior would be acted upon more and more slowly, and water penetrating through the crust would, being in smaller amount, first attack those carbides which are more easily decomposed. Occasionally masses of more refractory carbides, such as carbide of iron, carbide of aluminum, etc., would be passed by. Thus sporadic masses of such refractory carbides might remain until modern times when changes in the earth’s crust had provided reservoirs covered with relatively impervious material where our present deposits of petroleum might accumulate.

According to this theory, these processes may still progress.

One of the few experimental investigations as to this theory has been carried out recently by Mr. George F. Becker, United States Geological Survey. He has shown that ammonium chloride, a common constituent of volcanic emanations, when acting upon natural masses of iron, yields its chlorine to the iron, while the hydrogen of the ammonium chloride unites with the carbon in the iron to form petroleum. He has so acted upon natural iron carbide, found in the earth, as to actually make petroleum by such means. In fact, this process can be easily illustrated to you.

Mr. Becker has also called attention to the fact that where deposits of petroleum are known there the deviations of the magnetic needle are greatest. The association of petroleum with

magnetic material, practically iron or magnetite, seems much too close to be accidental, and it may indicate that an important part of the oil is derived from iron carbides; but Mr. Becker does not commit himself to any exclusive theory.

Organic.—By far the greater number of geologists and petroleum chemists prefer the theory that petroleum has been formed from the various residues of animal and vegetable life, stored in very large quantities in the sedimentary rocks where accumulations of oil are found. These scientists have differed very greatly as to the processes which have transformed organic residues into oil. Prof. Carl Engler and his scientific associate, Prof. Hans Höfer, are convinced that they have followed out the detailed steps of the process. In brief, they believe that in the ordinary processes of animal decay, taking place under ground, the portions consisting of fats remain after the rest of the organism has entirely disappeared. These fats are hydrolized, and the fatty acid portion loses oxygen and becomes oil. The different oils result both from varying original materials and from the varying degrees of heat and pressure by which the material has been distilled, with oil as the end product.

Other scientists do not adhere to so detailed a conception of all the stages of oil formation. Mr. David White, of the United States Geological Survey, has formulated exceptionally clearly the view quite generally held among scientific men. This theory is clear, logical, and consistent. First, by the aid of bacterial fermentation—a biochemical process—the plant and animal *débris* is partially disorganized, with the formation of new compounds, the decomposition being interrupted at some stage short of complete destruction. Second, by geochemical and geodynamic agencies the buried *débris* is compressed and subjected to a process of distillation which gradually alters the organic substance and drives off volatile matter. When the organic *débris* consists of peat of ordinary types, or of scattered *débris* of vascular types of plants, the organic deposits are transformed to coal or carbonaceous matter in the shales or sandstones, etc. When the organic *débris* consists largely of resinous and waxy plant products, such as spore covers, seed coats, etc., deposited in comparative purity, the geodynamically and geochemically altered material (much volatile matter being evolved) forms canneloid coals, such as cannel coal, and when the original organic *débris* contains much

algal matter, or matter supposed by most paleobotanists to be algæ, mixed with other plankton material in the muds,—that is, when the deposit is “sapropelic,”—the partially-altered residues are oil shale, oil rock, boghead, etc. In all these cases the material, whether coal, oil rock, or boghead, is already dynamochemically altered and partially distilled, some of the volatile matter (gases and oils) having already been expelled. The kinds of volatile matter depend on the geological conditions prevailing in each case, and the amount of the volatile and the extent of the reduction (“carbonization”) of the residues depend primarily on the energy and duration of the dynamic action, though varying according to the kinds of original *débris* of plants and animals. Gases are evolved in all cases, and are still being given off in many coal fields. Oils are believed to be produced by the natural dynamochemical distillation of cannel-forming *débris*, though the more distinctly “sapropelic” matter is supposed to include the principal substances from which petroleum is distilled in the earth.

In some cases these layers of sapropel apparently have become indurated into layers of shaly material which is still in condition to yield oil when under pressure.

Whether our bituminous shales have thus originated or whether they owe their organic matter to infiltrations is a point which may soon be cleared up.

How long the organic matter remains as sapropel before being converted into oil is questionable, but in my judgment the greater the proportion of the total period given to the first stage and the shorter the period assigned to the petroleum after actual formation, the more probable the theory.

At this point I would like to express my lack of faith in the conservatism of the statements frequently made that oil has actually been found in process of formation from seaweed on the surface of water. Scientific accuracy seems to be entirely lacking for these obviously improbable observations.

However the organic matter may have been converted into petroleum, we recognize that the oil was at first scattered in minute drops through the earth, and these gradually collected, largely driven by the superior capillary action of water into such porous rocks as can serve as good repositories, and where the oil is confined by comparatively impervious rocks—usually clays or shales

with their capillaries filled with water. During this process of accumulation it is quite possible that the character of the oil has essentially changed. Thus oils which have penetrated into shales are found to be simpler in their make-up than those in other rocks, such as limestones. It would seem from what we find that the shales have taken out part of the original constituents, and I have proved it possible to abstract certain parts of oils merely by diffusing these complex oils through dry clay.

How Our Various Oils are Utilized.—We can think of the petroleum which is produced in the West as all containing more or less of Pennsylvania oil, with greater or less admixture of asphalt, and, in the case of California oil, considerable proportions of members of the coal-tar series.

For a long time these Western oils were not taken at all seriously, inasmuch as the supply was abundant of Pennsylvania and West Virginia oils. Moreover, the Western oils,—that is, of Texas and California,—were very difficult to refine. A process was soon found for refining Texas oils, but the California oil remained a problem. While it was easy to remove the asphaltic material, the coal-tar oils, such as benzol, toluol, etc., distilled over with the illuminating oil and made it burn with a smoky flame. One of the chemical engineers of the Standard Oil Company of California found, however, that fuming sulphuric acid,—that is, sulphuric acid containing sulphur trioxide in solution,—has the property of taking out these coal-tar oils quite completely, and furnishing a very satisfactory kerosene. With this discovery the refining of California oils progressed rapidly in spite of the fact that in distilling off all the available kerosene the total proportion obtained was comparatively small. This difficulty of extracting coal-tar hydrocarbons from petroleum has been met with to even greater extent in Roumanian oils, and there a still more modern process has been applied, though too recently for an estimate of its practical value. By this the distillate containing coal-tar oils is treated with liquid sulphur dioxide, which extracts the coal-tar oils in preference to the paraffin hydrocarbons, and thus renders the latter suitable for lamp oils. This ingenious process, moreover, admits of separating, finally, the coal-tar oils in a condition suitable for use, whereas they are practically destroyed when separated by means of fuming sulphuric acid. Thus to-day there are no varieties of crude petroleum

in the United States which cannot be refined satisfactorily, although the yields of refined products in the West are by no means so great as with the Eastern oils.

Heavy Texas and California oils can also be made to yield very satisfactory lubricating oils. A process is under way which probably will give considerable yields of paraffin wax, even from California oils, in which, naturally, almost no paraffin wax is present.

The amount of oil refined and the amount used for other purposes are now merely questions in the United States of a market for the resulting products. If all our oils were used in the United States and not exported, the oils of the East and of Oklahoma would be an abundant source for all the desired kerosene, and perhaps gasoline as well, but about one-fifth of all our oil is exported in one form or another, especially kerosene.

As each year goes by, technologic improvements in the treatment of petroleum make this material more flexible for suiting all market demands, so that in general it may be said that enough oil is refined to meet the foreign and domestic demand, first, for kerosene and gasoline; then attention is given to the much smaller and more easily satisfied demand for lubricating oils; and, finally, to the ever-increasing demand for paraffin wax.

The rest of the product can always be gotten rid of at fairly lucrative prices for fuel oils. In fact, the price for fuel oil has almost doubled in the last five years.

In general, all of the Eastern oils are refined to the greatest possible extent, producing gasoline, kerosene, lubricating oils, paraffin wax, and a minimum of gas oil and fuel oils. In fact, it is the common practice to distil these oils entirely to coke with a production of practically no fuel oil.

As these oils are insufficient for the distillation needs of the country, large quantities of oil from Ohio, Indiana, Illinois, and Oklahoma are similarly refined to the utmost limit. The same is true of the oil from the Caddo (Louisiana) field and from the Electra region in northern Texas, where the oils are of Pennsylvania grade. Meantime the oils of Texas are largely used for fuel purposes, though a certain amount is sent in tank steamers to the Eastern States, or worked up at Port Arthur, on the Texas coast, for the production of superior lubricating oils.

Since all this does not suffice for the foreign and domestic

demand for refined products, Wyoming is called on for similar use of its light-grade oils, the production of which is increasing very rapidly in the Salt Lake field near Casper.

These oils above mentioned, comprising our total supply, apart from California, amounted to about 135,000,000 barrels in 1912, while California yielded 87,000,000 barrels more. This California contribution is the really flexible quantity. It can be used in so far as necessary for refining purposes, but principally as a great source of fuel oils and for road asphalts. This supply of fuel oil will enter significantly into Eastern commerce with the opening of the Panama Canal.

Since this lecture was prepared the United States Geological Survey has pointed out the existence of very large bodies of oil shales in Colorado and Utah which are richer than the Scottish oil shales. Some will yield two barrels of oil per ton by distillation, while the usual oil-bearing sands yield less than half that much. Shales yielding 30 gallons per ton of crude oil probably exist, according to estimates of Mr. E. G. Woodruff, of the Geological Survey, capable of yielding *15 billion barrels* of crude oil.

Imports.—Two other sources add to the total oil supply of the United States; namely, considerable imports of heavy Mexican crude oil, suitable principally for road asphalt and fuel oil. This Mexican importation will undoubtedly steady the price of fuel oil in the next year, as some twenty of the largest tank steamers afloat have been built for this trade and will bring large quantities to the Eastern ports. The second source is light distillate, yielding large proportions of gasoline and coming from Borneo and Java to Pacific ports. Thus while we are exporting gasoline on the Atlantic Coast we import it on the Western shore.

Our Relation to the Rest of the World.—The total production of petroleum in the United States is now, roughly, 240,000,000 barrels. This means two-thirds, and more, of all the petroleum produced in the world. And yet the first commercial development of significance took place barely half a century ago. There is now no sea whose waters are not churned by the propellers of oil-burning steamships, no country whose roads have not seen the gasoline motor car, and no village in the civilized world in which the flame of kerosene or some form of petroleum does not illuminate some house, and thousands of miles of highways are kept free from dust or otherwise improved by petroleum oil.

We owe our standing in national intelligence to the light of the kerosene lamp. We owe our greatest industrial characteristic—flexibility in manufacturing processes—to the national habit of reading. Kerosene light has been cheap, and is cheaper in the United States than anywhere else, and it has prevented all other lights from following the high price of living.

Foreign Ownership of American Oil.—Petroleum has had its share in developing American prestige. It has done more than precious metals or precious stones. Probably more people have used kerosene than have ever seen a gold coin. The petroleum and natural gas produced last year outvalued our gold, silver, lead, zinc, and all other metals combined, except iron and copper.

I offer these quantities merely to stimulate the natural inquiry as to how we are administering this trust of national, natural advantage: an advantage over less favored nations which it is a pledge of our patriotism to maintain. Are we maintaining it to the best purpose?

We are not. In no line of national conduct is the progress so recklessly devoid of any thought-out policy. Besides a system of production which considers neither supply nor demand at home, we squander our heritage over the face of the earth, and we do worse. It may well be claimed as good public policy that our oil should spread out to less favored lands as the handmaid of education where it will do the greatest good, and to this we must subscribe. No missionary can compete with the lamp, nor work without a lamp. But what policy broader than dollar greed can defend the sale of our greatest single weapon for national independence, our oil lands themselves, to foreign capitalists, if not to foreign nations?

Sir Marcus Samuel spoke in regard to this at the annual shareholders' meeting of the Shell Transport and Trading Company, Limited, in London, October 10th. The speech was given wide publicity in the English press.

The Shell Transport and Trading Company, Limited, is an important part of the immense petroleum combination of Europe, known as the Royal Dutch-Shell group, dominated by the Deutsche Bank and the Rothschilds.

Sir Marcus Samuel said, among other statements:

“The business is world-wide, and we are determined that the great distributing organization which we have created shall

not be dependent upon any one field, or upon any one country, or upon any one government. We shall endeavor to acquire oil territories, so essential to the support of our organization, wherever they can be found.

“It is mainly in pursuance of this policy that we have purchased the ‘Californian oil fields.’ It is in connection with that purchase that we are providing the large sums that we have asked you to subscribe.

“The business which we have obtained has been managed upon lines which commend themselves to us. From time to time properties have been purchased to strengthen the reserve of territory. The oil produced is among the very best obtained in California. We are satisfied that it is going to prove an excellent investment at the price we have paid for it, which was £400,000 in Shell ordinary shares and £400,000 in cash, 60 per cent. of which is provided by the Royal Dutch.

* * * * *

“The position of the companies in Roumania and in Russia continues highly satisfactory. In both countries we are the largest producers.

* * * * *

“In Mexico we have acquired, over carefully chosen territory, large areas at small cost.

* * * * *

“Borneo continues to show its extraordinary riches. It is the possession of that field which enables us to enter into contracts which we certainly would not commit ourselves to do without it. The wisdom of your directors in consolidating the interests of your company with those of the Royal Dutch Petroleum Company is proved constantly and daily.

* * * * *

“Other subsidiaries in which we are interested, and on which we have options on considerable blocks of shares at very much below current quotations, are doing well, and promise to increase the company’s earnings.”

* * * * *

The facts are open to every one, but recognized by few, that 25,000 barrels a day, over 12 per cent. of the oil in Oklahoma, are produced by foreign companies, and the foreign ownership in California is increasing even faster.

The chief significance of this is that practically every foreign power is adopting oil in place of coal for its battleships, and a supply of oil is requisite for this purpose.

There is no opportunity here to develop a policy, but there is an opportunity for directing thought, and I bespeak the influence of this time-honored institution, developed within the sound and in the spirit of our national Liberty Bell, in giving sympathy and counsel to our national government as to these problems when developing petroleum legislation.

Supply of Gasoline.—This consideration naturally suggests the vital question of an adequate gasoline supply. Even if we produce 25,000,000 barrels of gasoline in the next year, this would probably be too little for a year or two of further automobile progress.

The means for meeting the demand are in sight.

This answer is far easier to state than to explain. In the first place, recent developments in knowledge of the resources of the United States make it probable that there will be no great decline in oil production in the near future, therefore no *decline* in gasoline supply is likely. As to the necessary increase: this will come from synthetic gasoline obtained from petroleum itself. To make this clear, it is necessary to refer in great detail to the nature of petroleum. We know that this long series of oils which mixed together constitutes petroleum begins with oils which boil more easily than ether, and each following one in the series boils at a higher temperature. By distilling out those which boil below 300° F. we obtain from Pennsylvania oils about 20 per cent. of so-called naphtha. By redistilling this we obtain gasoline, but the naphtha itself is fairly suitable for automobiles. The mid-continent oils yield slightly smaller proportions of gasoline. The oils of northern Louisiana and Texas yield as much as Pennsylvania. The gasoline yield from the Gulf Coast of Texas and Louisiana and from California is very much less, so that at present the West coast is practically left out of consideration, and its gasoline is supplemented by importation from the Orient.

Cracking.—After the natural yield of gasoline has been taken from crude oils, the remaining portion boils at too high temperatures to be suitable for automobiles, although the higher-boiling kerosene is used successfully under exceptional conditions which cannot be considered here. Therefore the limit of gasoline would

seem to be reached—were it not for the fact that many oils break up into lighter oils when heated.

Thus, certain Mexican petroleums contain naturally only 2 per cent. of gasoline, but, by slowly heating, these oils break up so that they yield about 7 or 8 per cent. of gasoline. But these so-called “cracked” oils are bad smelling and difficult to refine. Several years ago I found that if these oils are distilled under pressure the yield of gasoline is still greater, and that the unpleasant odor due to deficiency in hydrogen in the composition of the oils can be remedied by actually combining hydrogen with the oil in the still under the influence of a catalytic agent. Recently the demand for any kind of gasoline has waived the requirement of good odor, and other processes are producing much synthetic gasoline. By such means low-grade residues have been made to yield from 20 to perhaps 70 per cent. of their weight in material which will serve as gasoline.

The Study of Individual Hydrocarbons.—The main difficulty in carrying out these processes is lack of knowledge of the behavior of individual oils when heated. At this point our fundamental study of individual hydrocarbons fails. It seems wise just at this time to encourage to the greatest extent the study of the characteristics of these individual hydrocarbons—not only to know more of the way they break up when heated, but to study the effect of chemical agents upon them in forming a long series of new substances and of old substances in cheaper or purer conditions.

To this plea for greater exactness of knowledge I would ask your earnest attention.

Nature of Petroleum.—But what are complex and what are simple oils? What is petroleum? Petroleum is so many things under so many conditions that at first it seems hopeless to attempt to define it.

Yet we can distinguish between petroleum and all other substances as being made up of hydrocarbons and frequently holding in solution those indefinite compounds of hydrogen and carbon, with oxygen or sulphur, or both, that we call asphaltic compounds.

There are so many hydrocarbons interdissolved in this complex mixture, usually containing different proportions of hydrogen to carbon, that they would seem to grade without solution of continuity from marsh gas through hydrocarbons containing

progressively more carbon. Meanwhile, blended with these pure hydrocarbons are, frequently, the asphaltic materials, which, with ever-increasing carbon, extend the complexity of the subject through gilsonite and grahamite to the indefinite border land of coal.

We recognize that a separation of this great mixture into all its simple oils is beyond the possibility of any one man, and—to further present, frankly, the sum of discouragement which this problem presents—while we are separating these constituents, many of them are broken up into still new oils by the very agents (heat, chemicals, etc.) which we use for their separation.

In spite of all this, the work of many scientists taken together has isolated one oil after another and simple individual oils have been taken out of the mixture. We all know that this has taught the encouraging fact that there is system in the variation of these oils one from another. We know that we can group the oils into a few homologous series, and in each series each oil differs from the next member by a definite amount of hydrogen and carbon, and with a difference in boiling-point which makes possible certain methods of separation. There is similar difference in viscosity, specific gravity, etc., which properties are also being availed of as aids in separation.

It is only recently that we have come to avail ourselves of properties which characterize each series as a whole in order to separate a whole group at once and then study its members.

Group Separations.—The first of these processes, historically speaking, has been to treat the complex oil with sulphuric acid, and by keeping the acid cold and using it sufficiently strong we can destroy and thus remove all of the groups except what we call paraffin hydrocarbons, and if we heat the oil we can easily attack these paraffin oils also. Lately other important processes have been added: thus Nastukoff in Russia has found that by treating oils with formaldehyde and sulphuric acid, condensation products are formed with certain groups of oils. Again, Holde and others have formulated methods for extracting certain kinds of asphalt from oils by precipitation with gasoline. These and other methods which it would lead us too far to consider have enabled Professor Engler to formulate a general method which it is believed will soon enable us, for purposes of study, to sufficiently separate a given petroleum into its groups of components,

and the study of each of these will soon give far better fundamental information of the constitution of our oils. Evidently many surprises await us as to the character of these individual oils. We are accustomed to think of the best of oils as having odors that are persistent and disagreeable. These we will find are due usually to slight amounts of impurities. Already we know odorless oils such as albolene and vaseline when fresh—that qualification “fresh” is significant and of promise. The very fact that oils develop an objectionable odor with age is significant when we learn that these odors are chiefly oxidation products allied to fatty acids, and of the greatest promise for the future production of such valuable substances as butyric, oleic, stearic, and other acids. We must look upon the individual petroleum oils, therefore, as the starting point for compounds of great utility. The greatest advance which has come in the consideration of the chemical derivatives from these oils is due to recognizing that these hydrocarbons are, after all, not the refractory inert substances that we have taken them to be, but susceptible by chemical treatment of yielding a host of products. Theoretically, this has long been possible—as a practical feature it is in its infancy. But already the oxidation products, such as fatty acids capable of being saponified into soaps, are being investigated in this city. Chlorine products are being made which offer strange new properties with suggestions of many new uses. Strangely enough, these chlorine products will not burn readily, and already some of these products of inflammable kerosene are used most effectively as fire extinguishers.

Improving Oils by Adding Hydrogen.—Another line of investigation is proving helpful in the direction of adding hydrogen to oils which owe their bad odor and color to lack of saturation. The chemical possibilities with these lower grade unsaturated products are problems for the future. We know at least that we can add hydrogen to them and then form the chlorine or oxygen products which have already been referred to, but beyond doubt their unsaturated condition will enable them to be acted upon directly to form other lines of valuable products. In fact, years ago, my brother, Dr. W. C. Day, then of Swarthmore College, indicated a line of valuable research by actually making good varnishes by treating waste unsaturated residues with nitric acid. We know little of what sulphur will accomplish in combination

with oils. The same is true of phosphorus and other active chemical agents. The very vastness of this field of research teaches one fundamental lesson, one suggested by the coal-tar industry. It is characteristic of that industry that the individual oils were easily separable from each other, so that the fundamental properties of each could be thoroughly studied once for all, and upon that basis of thorough and exact knowledge vast stores of useful application were quickly based, yielding us, besides aniline dyes, saccharine and a host of helpful medicines. But we have no such fundamental knowledge of petroleum oils. Can there be any doubt that the quickest, surest road to the knowledge of the chemical uses for petroleum for the most successful application of it in all ways must be by promoting the study of the individual components? Such exact, purely scientific, work must be carried out by an organized corps of workers supported by an endowment for this work, and be purely fundamental and kept distinct from industrial work, or it will prove too complicated for prompt completion. It is the work of many, but it may be begun by one—some one capitalist who will benefit all mankind by a foundation for petroleum research.

Salt in British Columbia. ANON. (*Mining and Eng. World*, Oct. 25, 1913.)—An extensive bed of salt has been discovered at Kwinitsa (mile 45, on Grand Trunk Pacific Railway), on the Skeena River. Up to the present five holes have been drilled, some more than a mile from others, and all have struck salt, at depths varying from 50 to 250 feet. About eight tons have been taken out. The principal salt wells of Canada are situated in Western Ontario. On account of the long rail-haul, most of the salt used in British Columbia is imported from California. The presence of salt beds near Vancouver is, therefore, of importance.

The Influence of Foreign Substances on the Activity of Catalysts. C. PAAL and A. KARL. (*Ber.*, xlv, 3069.)—It has been previously shown that the activity of palladium as a catalyst in hydrogenations was remarkably diminished when it was deposited on aluminum, iron, copper, silver, tin, or lead. It is now shown that the oxides, hydroxides, and carbonates of these metals behave in a similar manner. Basic lead carbonate entirely prevents hydrogenation, while zinc oxide, zinc carbonate, aluminum hydroxide, and ferric hydroxide greatly reduce it. Cadmium carbonate is also an anti-catalyst. On the other hand, magnesium oxide, like metallic magnesium, does not reduce the catalysis, but rather, on account of its greater surface, increases it.

Ductile Tungsten. C. G. FINK. (*Amer. Electrochem. Soc., Trans.*, xxii, 499.)—This article deals with the various applications of the metal in particular as a substitute for other more expensive or more easily corrodible metals. *Electrical Contacts.*—Wrought tungsten can successfully replace platinum and platinum-iridium alloys for contact points in spark coils, relays, etc., and, owing to the greater hardness, higher heat conductivity, and lower vapor pressure of tungsten as compared with platinum, the life is longer. Tungsten gauze is recommended for use in various chemical processes, while tungsten anticathodes for X-ray tubes are said to be more efficient than those of other metals. *Thermoelectric Behavior.*—The electromotive force of a tungsten-molybdenum couple increases with temperature up to about 540° C. (12½ millivolts), then decreases and passes through zero (millivolts) at about 1300° C.; this couple serving as a convenient measure of high temperatures in the tungsten-hydrogen furnace. *Standard Weights.*—Owing to its high density, 19.3 to 21.4, its indifference to atmospheric attack, and the fact that it can be made hard enough to scratch glass, tungsten is a suitable material, and the weights are said to remain wonderfully constant. *Suspensions and Micrometer Wires.*—Sizes down to 0.0002 inch have been drawn, and are well adapted for galvanometer suspensions, cross-hairs in telescopes, and for surgical uses, in place of the coarser gold and silver wires. Musical instruments might also be provided with tungsten wires in climates where steel is readily corroded. It is also suggested that it could advantageously replace phosphor-bronze in many cases.

Photo-electric Behavior of Iron. H. S. ALLEN. (*Faraday Soc.*, Nov. 12, 1913.)—Iron which is chemically active shows a relatively large photo-electric activity,—*i.e.*, it loses a negative charge fairly rapidly when insulated and illuminated by ultraviolet light. Processes which render the iron passive greatly reduce this activity. These facts are in good agreement with the theory that the cause of passivity is the presence of a gaseous layer at the metallic surface. This theory, like the oxide-film theory, was originally advanced by Faraday.

New Electric Pendulum. M. SCHANZER. (*Zeitschr. Instrumentenk.*, xxxiii, 218.)—This describes a new form of apparatus for electrically maintaining the motion of a pendulum. The energy consumption is very small, only 8 milliwatts; and the ratio of the length of arc during which the pendulum is driven, to the whole swing, is about 1:18, the pendulum thus swinging freely for the greater part of its motion. The pendulum itself is a quartz rod, 110 cm. long and 1.8 cm. diameter, so that there is only a small variation of length with temperature. The whole apparatus can be enclosed, so that the pendulum can swing *in vacuo* if required. The original paper gives diagrams and details of the mechanism.

RESISTIVITY OF PURE GOLD IN TEMPERATURE RANGE 20° C. TO 1500° C.*

BY

EDWIN F. NORTHRUP, Ph.D.,

Member of the Institute.

IN obtaining data for tracing the resistivity of pure gold from 1500° C. to below its freezing point, the method and apparatus employed were in all essential respects the same as were used in the measurements of copper, which were fully described by the writer in the JOURNAL OF THE FRANKLIN INSTITUTE for January, 1914. A full description of the furnace used may be found in *Metallurgical and Chemical Engineering*, January, 1914.

The gold used in the measurements was purchased from Baker and Company, Inc., Newark, N. J. In making the purchase it was requested that gold of the greatest obtainable purity should be furnished. The Baker Company wrote that they would prepare and ship "the chemically pure gold wire as covered by your specifications." No analysis of the gold was made to determine if these specifications had been met. The resistivity, 2.316_6 at 20° C., is fairly low and shows that the gold must have been at least approximately pure.

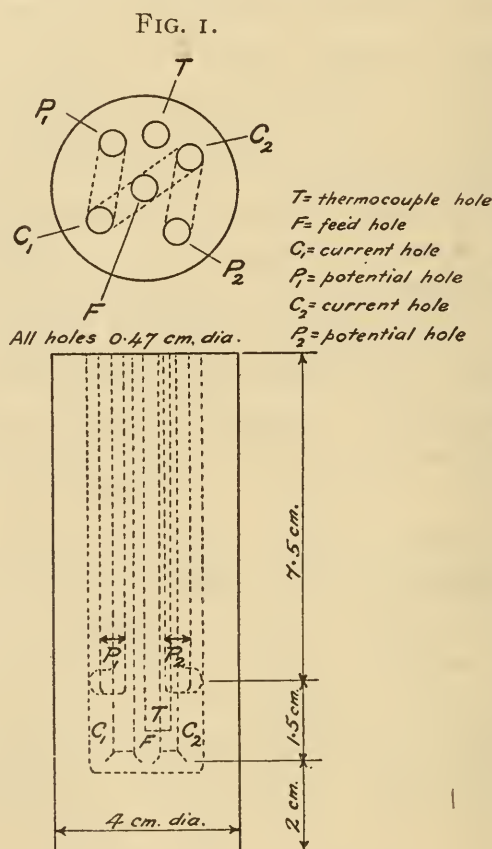
The containers for the molten gold were constructed in the same manner as those used for copper, but the dimensions were changed in certain respects. The diagram Fig. 1 shows the dimensions chosen for gold container No. VI. It will be noted that the potential terminals join the current circuit only 1.5 c.m. above the lowest part of this circuit. Experience shows that the length of the channel of molten metal being measured is quite sufficient for adequate sensibility, and by choosing the point where the potential holes join the current circuit low down, the temperature can be made almost exactly uniform over the portion of the circuit the resistance of which is measured.

Further experiments indicated that a better proportion, than formerly used, of alundum and magnesite for making the containers is: magnesite 45 parts and alundum 55 parts. These proportions are now adopted for all this work.

A method was devised for tracing the resistivity of the gold

* Communicated by the author.

in the solid state from 20° C. to its melting-point which proved to be accurate and very easy to apply. It was carried out as follows: The gold was in the form of wire 0.1013_3 cm. diameter. The resistivity of this wire at 20° C. was determined in an oil bath, by the method of the Kelvin double bridge, and found to be 2.316_6 microhms per centimetre cube. This same gold wire was wound into a helix about 1.5 cm. long, with the turns well separated. The diameter of the helix was such that the end of a porcelain tube about 0.5 cm. in diameter would pass into it. The porce-



lain tube contained the thermocouple. Gold wire potential leads were electrically welded to the gold wire near each end of the helix. Over the four terminals thus formed porcelain tubes were slipped to electrically insulate the leads from each other. The arrangement so formed was put on the inside of a large quartz tube and centrally located in the furnace chamber. The four gold wire terminals, two current and two potential leads, passed through small holes in the baked lavite-cover piece of the furnace. It was now possible to determine the resistance by means of the Kelvin double bridge of the helix of gold wire between the

points where the potential terminals were attached and, at the same instant, to read the electromotive force of the thermocouple with a potentiometer. By slowly heating the furnace, 31 points for a curve relating resistance and temperature were obtained. The last reading was at a temperature of 1070° C., when the circuit completely opened from the melting of the wire. Indications of a change of resistance began at 1063° C. It is probable that the surface tension of the wire preserves the circuit for a short time after fusion begins.

Having the resistance values from 20° C. to the melting-point of gold, and knowing the resistivity at one temperature, the constant could be calculated by which all resistance values must be multiplied to obtain resistivities for corresponding temperatures. The points for the curve as plotted in the solid state were obtained in this way.

The thermocouple, used in all the gold measurements, was a platinum *vs.* platinum + 10 per cent. rhodium couple, encased in a glazed tube of Royal Berlin porcelain. This thermocouple was calibrated by the writer by using the melting-points of different metals for giving fixed temperatures. The method which the writer has found most convenient for calibrating a couple in this way is the following: The metal to serve for the fixed temperature, pure nickel for example, is selected in the form of wire, about No. 22 or 24. This wire is doubled on itself and one half of its length is insulated from the other half with small-bore porcelain tubes. The doubled wire is mounted in a larger porcelain tube exactly as one would mount a thermocouple. This tube and the tube of the thermocouple to be calibrated are laid together and placed in the furnace. A storage cell, 5 ohms resistance, and a buzzer are connected in series. The two ends of the wire, which is to give the fixed point of temperature, are joined to the terminals of the buzzer, which thus becomes shunted so long as the wire is intact. The instant the wire melts the buzzer sounds, at which moment the electromotive force of the thermocouple is read with a potentiometer. If the furnace has a large chamber, various wires, as tin (232° C.), cadmium (320.2° C.), silver (960° C.), gold (1062.4° C.), copper (1082.6° C.), nickel (1452.3° C.), and palladium (1549.2° C.), may be mounted, each in a separate tube, and all these tubes, together with the thermocouple tube, can be bound together in a bundle, their ends coming to the same

level, and be mounted in the furnace. The temperature may be raised slowly and the electromotive force of the thermocouple read at the instant each metal melts, as the temperature is raised. This is the general plan which the writer adopts for the calibration of his thermocouples.

After the experience, acquired in the measurement of copper and other metals, it appeared entirely practicable to expect to have independent determinations of the resistivity of gold, in the neighborhood of 1200°C. , to agree to better than 0.25 of 1 per cent. This expectation has been realized in the case of gold. For example, under similar conditions of slow cooling, the resistivities obtained in the measurement of December 20, 1913, at 1218°C. and 1140°C. , were respectively 33.00 and 32.00 microhms, container No. V being used, and the resistivities obtained in the measurement of January 10, 1914, at 1217°C. and 1140°C. , were exactly the same, container No. VI being used. The writer has considered that all determinations of the resistivity of pure metals in the liquid state should be made at least twice, using a different container having a different constant for each determination. When this is done and the agreement is close, one's confidence in the precision of the results is secure. As the writer has previously stated, the resistivity of a metal in its molten state is independent of its past physical history, and depends only upon its temperature and its purity. It, therefore, is desirable to be able to measure the resistivity of molten metals with high precision, because of the information which such measurements of precision can give regarding the chemical purity or chemical constitution of the metal or alloy. It is a satisfaction to find that a measurement may be made in which the error is not greater than 0.25 of 1 per cent. when a metal is in its molten state, and with more experience even better results may be expected.

Since the report made on copper the writer has acquired information about a matter of extreme importance connected with this method of measurement. It is this: Unless the material, of whatever nature apparently, of which the container is constructed is fired to a temperature in excess of that to which the measurement is to be carried, the container will evolve impurities which will contaminate the molten metal and permanently change its resistance. In the first measurement of the resistivity of

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gold in the molten state the magnesite-alundum container used had only been preheated to 1250°C . A glance at the curve (see dotted line) will show that at just about this temperature the increase in the resistivity of the gold being measured was more rapid than a linear relation. If only one determination had been made it would have been wrongly concluded that the increase in resistivity of gold in the liquid state is not linear after 1250°C ., and that the resistivity at 1500°C . is 40 microhms, whereas the true resistivity is but 37.2 microhms. As the writer was confident that the more rapid increase in resistance above 1250°C . was due to an increasing contamination of the gold by matter evolved from the container, he prepared in a second determination for an avoidance of this contamination by preheating the second container used to a temperature in the neighborhood of 1600°C . As was expected, the increase in resistivity of gold in the liquid state, as found in the second determination, is strictly linear up to the highest temperature at which resistivity was measured, which was 1467°C .

TABLE I.

Resistivity Values for Pure Gold in Temperature Range, 20°C . to 1500°C .

Degrees Cent.	Microhms per centimetre ³	Ratios ρ_t/ρ_{t_1}	Remarks.
20	2.316 ₆		Gold solid.
300	4.72		Gold solid.
500	6.62		Gold solid.
800	9.94		Gold solid.
1000	12.54	$\frac{\rho_{1000}}{\rho_{20}} = 5.411$	Gold solid.
1063	13.50	$\frac{\rho_{1063}}{\rho_{20}} = 5.827$	Gold solid.
1063	30.82	$\frac{\rho_m}{\rho_s} = 2.283$	Gold molten.
1100	31.34		Gold molten.
1200	32.76		Gold molten.
1300	34.17		Gold molten.
1400	35.58		Gold molten.
1500	37.00	$\frac{\rho_{1500}}{\rho_{1000}} = 1.181$	Increase per degree = 0.014142.

The results of all observations taken are embodied in curves. Thirty-one points were observed for gold in the solid state, fifty-three points for gold measured in container called No. V, Decem-

ber 20, 1913, and forty-two points for gold measured in container called No. VI, January 10, 1914. It would only lead to confusion to place all these points, many of which fall at the same place, on the curves. Only a few points which are typical are therefore shown. A table of the more important values is given.

The writer is again indebted to his wife for her assistance in taking the observations and working up the data.

He desires to reserve for a later paper comments upon the interpretation to be placed upon the observed facts and his conception of their significance as bearing upon the electron theory of metallic conduction.

PALMER PHYSICAL LABORATORY,
PRINCETON, N. J.

Copper-Covered or Copper-Clad Steel. J. O. HANDY. (*J. Ind. Eng. Chem.*, v, 884-895.)—A brief description of the manufacture, properties, and uses of steel covered with a layer of copper, either by alloying or welding, and including extracts from patent specifications and a bibliography of United States, English, German, French, and Belgian patents on the subject. It is stated that a union capable of withstanding mechanical working can be obtained both by the alloying method, in which the copper is melted, and by welding, when the copper is only rendered plastic by heating, for example to 950° C. Melted copper dissolves iron very rapidly, and since the electrical conductivity of copper is diminished by the solution of iron therein, the welding process is more satisfactory for the manufacture of copper-clad wire. Sheets of copper-clad steel exposed to the moist, acid atmosphere of Pittsburgh showed very little corrosion, even after two years. Copper-clad wire is now largely used, but the use of other forms of copper-clad steel might advantageously be extended in many directions, especially for constructional purposes.

Radio Elements and their Electro-chemical Behavior. F. PANETH and G. v. HEVESY. (*Monats. Chem.*, xxxiv, 1593.)—The chemical identity of certain radio elements with other elements, referred to by Soddy, extends also to their electro-chemical behavior. The decomposition potential of thorium C₁ and radium E is the same as that of bismuth, that of radium D and thorium B the same as that of lead, and that of radium A about the same as that of polonium. The electrolytic separation of thorium C₁ and radium E is for this reason retarded by the addition of bismuth, and that of thorium B by lead, and these facts may be utilized to obtain a more complete separation of radio elements than has been possible hitherto.

THE PRESENT PHYSICAL KNOWLEDGE OF X-RAYS.*

BY

WHEELER P. DAVEY,

X-Ray Laboratory, Department of Physics, Cornell University.

GENERAL PROPERTIES OF X-RAYS.

THERE are certain general properties which are common to all X-rays. Among these are:

- (1) The fluorescent effect.
- (2) The photographic effect.
- (3) The ionizing effect.
- (4) The chemical effect.
- (5) The action upon a selenium cell.
- (6) The penetrating effect.
- (7) The physiological effect.

(1) Certain uranium compounds and certain salts of alkali and alkali-earth metals have the property of giving off light when exposed to the action of X-rays. When the intensity of the radiation is increased (as, for instance, by bringing the source nearer) the intensity of the fluorescent light is increased. Röntgen¹ does not find any general simple relation between the P. D. applied to the tube (as measured by the current in the primary of his induction coil) and the amount of fluorescence produced on a screen of barium platino-cyanide, but states that in some cases he has been able to get the two in direct proportion to each other. But with constant conditions of excitation for a given X-ray tube, the intensity of the fluorescent light from the screen always varies inversely as the square of the distance from the screen to the target of the tube.

(2) The action of X-rays upon a photographic plate at a given distance from the tube depends partly upon the current sent through the tube and partly upon the penetrating ability of the rays employed. Other things being equal, an increase in the current hastens the photographic action, while an increase in the penetrating ability of the rays makes it slower. Two X-ray

* Communicated by the author.

¹ W. C. Röntgen, *Wied. Ann. d. Phys. u. Chem.*, 64, 1898.

beams which produce equal effects upon a fluorescent screen do not necessarily produce equal effects upon a photographic plate.²

Luther and Uschkoff³ thought they detected a difference between the action of X-rays upon a silver gelatino-bromide plate and that of light upon the same plate. It is possible that their results may be explained upon the same basis as solarization.

(3) If a gas is exposed to an X-ray beam, it is broken up into ions, or electrically-charged atoms. While the quantity of charge carried by different ions is not always the same, still it is always some exact whole number times 4.9016×10^{-10} electrostatic units of charge.⁴ The sum of all the charges carried by all the ions of a given sign is often used as a measure of the quantity of radiation which has produced them. As the sum of all the + charges must necessarily exactly equal the sum of all the - charges it is immaterial which sign of charge is used in the measurement. The amount of ionization produced in a gas in a given time depends upon the inverse square of the distance from the target of the tube,⁵ the P. D. applied to the tube,⁶ the penetrating ability of the rays,^{7 8} the nature of the gas,⁹ the pressure of the gas,^{6 7 8} but is independent of the temperature of the gas.^{9, 10}

(4) Except for the action of X-rays upon the materials in the film of a photographic plate, the only chemical actions so far noticed seem to be a precipitating effect, a dehydrating effect, a hydrolytic effect. Iodine is precipitated from its solution in chloroform by exposure to the rays.¹¹

Schwartz has found an ammonium oxalate-mercury bichloride

² W. C. Röntgen, *loc. cit.*

J. O. Heinze, Jr., *Amer. Jour. Sci.*, 13, pp. 313-314, April, 1902.

³ R. Luther and W. A. Uschkoff, *Phys. Zeitschr.*, 4, pp. 866-868, Dec. 15, 1903.

⁴ R. A. Millikan, *Science*, 32, pp. 436-448, Sept. 30, 1910.

⁵ E. W. B. Gill, *Phil. Mag.*, 23, pp. 114-121, Jan., 1912.

⁶ W. Hillers, *Wied. Ann.*, 68, 2, pp. 196-232, 1899.

⁷ R. K. McClung, *Phil. Mag.*, 7, pp. 81-95, Feb., 1904. *Nature*, 69, pp. 462-463, March 17, 1904. *Phil. Mag.*, 8, pp. 357-373, Sept., 1904.

⁸ C. G. Barkla, *Nature*, 80, p. 187, April 15, 1909.

⁹ J. A. Crowther, *Camb. Phil. Soc. Proc.*, 15, pp. 34-37, Feb. 23, 1909. *Roy. Soc. Proc.*, Ser. A, 82, pp. 103-127, March 10, 1909.

¹⁰ J. H. Clo, *Astrophys. Jour.*, 33, pp. 115-124, March, 1911.

¹¹ H. Bordier and J. Galimard, *Arch. d'Elec. Med.*, 14, Aug. 10; Sept. 10, 1906.

mixture which precipitates calomel under the action of X-rays.¹²

Ammonium, potassium, barium, and magnesium platino-cyanides change color when exposed to X-rays, due to dehydration.¹³

When starch is exposed to the rays it is changed into soluble starch and then into dextrin.¹⁴

(5) X-rays affect the electric resistance of a selenium cell in the same manner as light.¹⁵

(6) All substances exert more or less of an absorbing effect on X-rays. In general, the absorbing effect of any given substance for a given bundle of rays depends upon the material used as a target in the tube, the nature and thickness of the absorbing substance, the history of the radiation after leaving the target, and the P. D. across the tube at the instant the given bundle of rays is given off. In general, if the target of the tube is a substance of high atomic weight, then rays from that tube will be less readily absorbed than if the target had been of low atomic weight.

When rays from an ordinary X-ray tube pass through a substance, some of the radiation is absorbed, so that the emergent beam acts more feebly on a fluorescent screen, photographic plate, selenium cell, or ionizing chamber. If rays from a platinum-target tube, operating under ordinary working conditions, are made to pass through silver, then the intensity of the emergent beam may be calculated from the formula,

$$I_2 = I_1 e^{-\lambda x}$$

in which I_1 = intensity of the incident beam.

I_2 = intensity of the emergent beam.

e = base of natural logarithms = 2.7182 +.

x = thickness of the absorber.

λ = coefficient of absorption of the substance used as absorber. λ is very approximately independent of the thickness of the silver.¹⁶

¹² G. Schwartz, *Wein. Méd. Presse*, 1906, xlvii, 2092. *Electrotech. u. Maschinenbau*, 25, p. 452, June 9, 1907.

¹³ Bordier and Galimard, *Arch. d'Elect. Med.*, May 10, 1905.

G. Holzknicht, *Arch. d'Elect. Med.*, Oct. 10, 1910.

¹⁴ Colwell and Russ, *Arch. of Middlesex Hosp.*, xxvii, p. 63.

¹⁵ Perreau, *Comptes Rendus*, 129, pp. 956-957, Dec. 4, 1899.

Athanasiadis, *Ann. d. Phys.*, 27, 4, pp. 890-896, Nov. 26, 1908.

¹⁶ J. Beloit, *Arch. d'Elect. Med.*, Aug. 10, 1910.

All substances for which the above law holds true are said to be "aradiochroic." If, however, the rays are made to pass through sheets of aluminum, tin, etc., the above law does not hold. The value of λ as calculated by the formula is different for different thicknesses of the absorbing sheet, but as the thickness is increased, λ approaches more and more nearly to a constant value,¹⁷ and the law holds approximately if the sheet is thick enough. The formula may also be made to apply approximately if the difference in thickness between two absorbing sheets is so small that the value of λ has not changed appreciably, due to the change in thickness. Absorbers which act in this way are said to be "radiochroic," and are often called "filters."

These facts may be explained by assuming that an X-ray tube sends out a complex radiation ("heterogeneous beam") having two, and sometimes three, components. For the justification of this assumption see page 302. In aradiochroic substances the coefficients of absorption for the component beams are approximately the same. In radiochroic substances the beams are unequally absorbed. If the filter is thick enough to completely absorb all but one of the components, the emergent beam is said to be "homogeneous," and the absorption law will hold accurately for any absorber through which the beam may subsequently pass, provided no secondary rays are produced. It is to be noticed that no substance is *absolutely* aradiochroic. Silver is probably the most nearly aradiochroic metal for the rays given off by a tube with a platinum or platinum-iridium target, but is quite radiochroic for the rays given off by a lead target,¹⁸ being more opaque to the "secondary" component than to the "primary" component of the beam. If the absorber is of the same material as the target, it is more opaque to the "primary" component than to the "secondary" component. But the two absorption coefficients may be so nearly equal as to cause the absorber to appear under some conditions to be almost completely aradiochroic.¹⁹

If the absorber is of the same material as the target, then

¹⁷ W. Seitz, *Am. d. Phys.*, 27, 2, pp. 301-310, Oct. 15, 1908.
J. Beloit, *loc. cit.*

¹⁸ W. R. Ham, *Phys. Rev.*, xxx, 1, Jan., 1910, pp. 104-105, 118-120.

¹⁹ G. W. C. Kaye, *Camb. Phil. Soc. Proc.*, 14, pp. 236-245, Oct. 15, 1907. *Roy. Soc. Proc. Phil. Trans. A*, 209, pp. 123-151, Nov. 19, 1908.

W. R. Ham, *Phys. Rev.*, xxx, 1, p. 112, Jan., 1910.

λ decreases as the P. D. across the tube is raised, and the decrease of λ with the increase of P. D. is much more marked the higher the P. D. employed.²⁰

If the absorber is a chemical compound, the total absorption under any specified conditions is the sum of the various absorptions caused under those conditions by the various atoms and radicals of which the absorber is composed.²¹

(7) When X-rays are directed toward a given layer of flesh, in general, some of them pass through, while others are absorbed and give up their energy to the flesh. If sufficient energy is thus delivered to the flesh, serious pathological changes result which are of great importance from the view-point of the physician, but which do not concern the physical investigator, aside from the question of his own self-protection. A person in good health may have several radiographs taken (sufficient for ordinary diagnostic work) by a well-informed operator, without any danger of an X-ray burn, but the operator, or research-physicist, must, because of the possibility of long-continued exposure, or more often because of frequent repetition of short exposures, protect himself most carefully. The German Röntgen Society²² recommends that the protection consist of at least two millimetres of sheet lead, eight millimetres of X-ray proof rubber impregnated with lead, or lead glass from ten to twenty millimetres thick.

(8) Besides exhibiting the above-mentioned characteristic properties, X-rays also show properties which have caused them to be classed as a form of wave motion. When a narrow beam of X-rays is passed through a crystal parallel to a cleavage plane the emergent beam is broken up into a number of smaller beams symmetrically placed so that the effect as shown on a photographic plate, gives the appearance of a diffraction pattern.²³

Stark²⁴ contends that this is not a true diffraction pattern,

²⁰ W. R. Ham, *Phys. Rev.*, xxx, 1, pp. 108, 111-113, Jan., 1910.

²¹ W. Seitz, *Phys. Zeitschr.*, 13, pp. 476-480, June 1, 1912.

Blennard and Labesse, *Comptes Rendus*, 1896, cxxii, pp. 723-725.

²² *Archives of the Röntgen Ray*, July, 1913.

²³ W. Friedrich, P. Knipping, M. Laue, *K. Bayer. Akad. München. Ber.*, pp. 302-322, 1912. *Le Radium*, 10, pp. 47-57, Feb., 1913.

M. de Broglie, *Comptes Rendus*, 156, pp. 1011-1012, March 31, 1913.

T. Terada, *Nature*, 91, pp. 125-126, April 10, 1913; p. 213, May 1, 1913.

²⁴ *Phys. Zeitschr.*, 13, pp. 973-977, Oct. 15, 1912.

but most writers assume that the evidence points toward a true diffraction, and the theoretical basis of such an assumption is given by M. Laue, W. L. Bragg, and G. Wulff.²⁵

The results of Friedrich and Knipping's experiments point to a wave length for X-rays of the order of 10^{-9} cm. This is of the same order as the value given by Plank's theory and as the value found by Walter and Pohl.²⁶

When a pencil of X-rays is allowed to impinge on the cleavage face of a crystal at grazing incidence, a portion of the beam is reflected and the angle of reflection is equal to the angle of incidence.²⁷ Since this reflection is from the molecules of the cleavage face, the effect corresponds to that obtained when light is allowed to fall on a reflection diffraction grating, and there appears not only the truly reflected beam, but also a series of interference bands.²⁸

Experiments with magnetic fields show that no measurable deflection is produced even by a magnetic field of 19,000 gauss. No experiments on the velocities of X-rays have been conclusive.

PRIMARY X-RAYS.

If negatively-charged particles of matter (variously called corpuscles, β particles, cathode rays, and electrons) are shot out at high velocities toward a target, they will experience a great decrease in velocity upon entering the face of the target, and during the time that this decrease in velocity occurs, X-rays are produced. Such rays are called "primary rays." Although the point has not been as yet definitely settled, their properties

²⁵ W. Friedrich, P. Knipping, M. Laue, *loc. cit.*

W. L. Bragg, *Camb. Phil. Soc. Proc.*, 17, 1, pp. 43-57, Feb. 14, 1913.

G. Wulff, *Phys. Zeitschr.*, 14, pp. 217-220, March 15, 1913.

²⁶ Walter and Pohl, *Ann. d. Phys.*, 29, 2, pp. 331-354, May 21, 1909.

²⁷ W. L. Bragg, *Nature*, 90, p. 410, Dec. 12, 1912.

C. G. Barkla and G. H. Martyn, *Nature*, 90, p. 435, Dec. 19, 1912.

²⁸ C. G. Barkla and G. H. Martyn, *Nature*, 90, p. 647, Feb. 13, 1913. *Phys. Soc. Proc.*, 25, pp. 206-214, April 15, 1913.

E. Hupka and W. Steinhaus, *Deutsch. Phys. Gesell. Ver.*, 15, 5, pp. 162-163, March 15, 1913.

H. B. Keene, *Nature*, 91, p. 111, April 3, 1913.

E. A. Owen and G. G. Blake, *Nature*, 91, p. 135, April 10, 1913.

H. S. Allen, *Nature*, 91, p. 268, May 15, 1913.

E. Hupka, *Nature*, 91, p. 267, May 15, 1913.

seem to depend only upon the rate of retardation which the charged particles experience at the target, and this, in turn, depends very approximately upon the square root of the P. D. across the tube, upon the pressure of the gas in the tube, and upon the atomic weight of the target.

When the kathode rays strike the target, they are not stopped instantaneously at the surface, but merely suffer retardation, so that they penetrate for some distance into the body of the target. After once entering the target, the particles no longer all move in the same general direction, but travel more or less radially. If, for a given velocity of kathode rays, we imagine the target to be made thicker and thicker, a thickness will be reached at last for which there are as many particles emerging in one direction as in any other. This thickness is called "The depth of complete scattering."²⁹ In aluminum it is .015 cm.; in copper, .001+ cm.; in silver, .001+ cm.; in gold, .00020 cm.; in lead, .00025 cm. at 90,000 volts. It varies directly as the voltage employed across the tube.

Those primary rays which are able to overcome the absorbing effect of the target reach the surface and emerge into the vacuum space of the tube. Measurements have shown³⁰ that if the P. D. across the tube is made very small, then the primary rays, at the moment of generation, have their maximum of intensity in a direction perpendicular to the kathode stream, and a minimum of intensity in a direction parallel to the kathode stream. This effect is called "polarization." As the P. D. across the tube is increased, the polarization is decreased, until finally it becomes immeasurable. This is explained by assuming that at the higher potentials the rays formed by the initial retardation of the kathode

²⁹ J. A. Crowther, *Roy. Soc. Proc.*, 80 A, pp. 186-206, March 5, 1908.

W. R. Ham, *Phys. Rev.*, xxx, 1, pp. 119-121, Jan., 1910.

³⁰ R. Blondlot, *Comptes Rendus*, 136, pp. 284-286, Feb. 2, 1903. *Nature*, 9, p. 463, March 17, 1904.

C. G. Barkla, *Roy Soc. Phil. Trans.*, 204, pp. 467-479, May 31, 1905. *Roy. Soc. Proc.*, 74, pp. 474-475, March 16, 1905.

H. Haga, *Konink. Akad. Wetensch. Amsterdam Versl.*, 15, pp. 64-68, July 20, 1906.

J. Herwig, *Ann. d. Phys.*, 29, 2, pp. 398-400, May 21, 1909.

E. Basseler, *Ann. d. Phys.*, 28, 4, pp. 808-884, March 16, 1909.

L. Vegard, *Roy. Soc. Proc.*, Ser. A, 83, pp. 379-393, March 22, 1910.

W. R. Ham, *Phys. Rev.*, xxx, pp. 96-121, Jan., 1910.

F. C. Miller, *FRANKLIN INST. JOUR.*, 171, pp. 457-461, May, 1911.

stream are negligible in their effects when compared with those rays which come out in all directions from the depth of complete scattering.

SECONDARY RAYS.

When X-rays of sufficient penetrating ability are made to impinge upon a substance, that substance itself becomes a source of X-rays, which are called "secondary rays," and in general these secondary rays have penetrating abilities widely different from the exciting or "primary" rays, and the penetrating ability depends upon the substance used as a radiator.³¹

Radiators may be divided in the order of their atomic weights into four groups, as shown below. The radiations given out by the members of each group are very much alike.

Group 1 (1-32).—H-S. When excited by a beam from a "soft" tube the members of this group give off little, if any, real secondary radiation, but rather a scattered (one might almost say "diffusely reflected") radiation which is of the same nature as the exciting beam, and which is polarized in a plane perpendicular to the direction of the parent cathode stream. If the tube is made moderately "hard" (*i.e.*, if it gives off moderately penetrating rays), then a slight amount of true secondary radiation shows itself, and if the tube is very "hard," a well-defined secondary beam is given off having a penetrating ability much different from that of the exciting rays.

Group 2 (52-65).—Cr-Zn. This group gives off a beam composed almost entirely of a true homogeneous secondary radiation even when excited by rays from a "soft" tube, but this radiation has little penetrating ability. With a given excitation, the ionization produced by it is almost 100 times that produced by an equal mass belonging to group 1.

Group 3 (107-125).—Ag-I. If the exciting beam is only of moderate penetrating ability, this group gives off mostly a scattered radiation, but, unlike that from group 1, it is unpolarized, and there is a noticeable amount of true secondary radiation present. The relative amounts of scattered and secondary radiation vary greatly with small changes in the character of the exciting rays.

³¹C. J. Barkla and C. A. Sadler, *Nature*, 77, pp. 343-344, Feb. 13, 1908. *Nature*, 80, p. 37, March 11, 1909.

Group 4 (183-206).—W-Bi. These substances resemble group 2 in their action. For all the above elements the penetrating ability of the true secondary rays is independent of the intensity or of the penetrating ability of the exciting beam, but is a periodic function of the atomic weights of the radiating elements.³²

If the radiator is a chemical compound, the component atoms and radicals determine the character of the secondary rays produced.³³

The rays coming from salts are composed of (1) a homogeneous radiation having the same penetrating ability as that from the metal itself, and (2) a scattered primary radiation considerably more penetrating than (1) due to the acid radical. If a metal occurs in the acid radical it has no individual effect, but merely acts along with the rest of the radical.³⁴

Barkla and Sadler³⁵ have shown that if the incident primary rays are less penetrating than are the secondary rays which are characteristic of the radiator used, then no secondary rays are produced, but if the incident primary rays are more penetrating than the characteristic secondary radiation, then secondary rays are produced.

The production of secondary X-rays is very analogous to the production of fluorescent light. In fact, the analogy is so close that some writers are adopting the term "Fluorescence Röntgen radiation." If the penetrating ability of the exciting primary rays is increased beyond that necessary to first excite secondary radiation, it is often possible to obtain from the same radiator still another group of secondary rays having a different penetrating ability than the first, but this second group seems always to be identical with the first group from some other radiating substance.³⁶

Chapman and Piper³⁷ tried to detect a continuance of secondary radiation after excitation from the primary rays had ceased, but were unable to detect even 1/250 of the original

³² C. G. Barkla and C. A. Sadler, *Phil. Mag.*, 16, pp. 550-584, Oct., 1908.

³³ J. A. Crowther, *Phil. Mag.*, 14, pp. 653-675, Nov., 1907.

³⁴ J. L. Glasson, *Camb. Phil. Soc.*, pp. 437-441, June 14, 1910.

³⁵ Barkla and Sadler, *Nature*, 80, p. 37, March 11, 1909.

³⁶ R. Whiddington, *Nature*, 88, p. 143, Nov. 30, 1911.

J. C. Chapman, *Roy. Soc. Proc.*, Ser. A, 86, pp. 439-451, May 8, 1912.

³⁷ Chapman and Piper, *Phil. Mag.*, 19, pp. 897-903, June, 1910.

radiation $1/3000$ second after the exciting primary rays were removed.

It was stated on page 299 that the primary rays from the target of an X-ray tube must pass through a thickness of the target before they can emerge. It would be expected that such rays would excite that secondary radiation which is characteristic of the substance used as a target. There is also some evidence to show that the kathode stream itself may cause the target to give off its characteristic radiation if the velocity of the kathode stream is large enough.³⁸

Ham³⁹ has been able, by the use of proper absorbers, to filter out the secondary rays coming from his tube, leaving only the primary rays. He found that the ratio of the secondary radiation to the primary was increased by an increase in the P. D. across the tube. The rays coming from an ordinary X-ray tube are, therefore, heterogeneous, and since the P. D. necessary to cause a discharge to pass through the tube varies with the condition of the tube this heterogeneity is constantly changing.

On account of the wide variation in the character of the rays from tubes with the P. D. and current employed from instant to instant, it is essential that practically all experimental data concerning the action of X-ray tubes or of the rays themselves be accompanied by a statement showing:

(1) The P. D. employed and its wave form. If the maximum P. D. is measured by a spark-gap, the exact shape and dimensions of the terminals of the gap should be given. If the P. D. is measured by some other means, complete description should be given. If the wave form is not known, *complete* description should be given of the means used to obtain the exciting current.

(2) The number of milliamperes used and the kind of milliammeter used (that is, E. M., hot-wire, etc.). If the tube is of the Lilienfeld type,⁴⁰ the size of the regulating current must also be given.

(3) Exact description of the tube, including maker's name, serial number (if any), classification given by maker, dimensions, material used as target, hardness of tube at time of experiment,

³⁸ R. T. Beatty, *Roy. Soc. Proc.*, Ser. A, 87, pp. 511-518, Dec. 13, 1912.

³⁹ W. R. Ham, *loc. cit.*

⁴⁰ *Fortsch. a. d. Gebiete d. Röntgenstrahlen*, vol. 20, No. 5, 1913, p. 448.

and condition of tube (*i.e.*, "grows harder with use," "hardness nearly constant," or "grows softer with use").

(4) Number of seconds the tube is used for one "run." Much of the published data to date is useless because of the failure to record one or more of the items mentioned above, since without such information the results can neither be interpreted properly nor exactly duplicated by any other experimenter.

MEASUREMENT OF QUALITY, QUANTITY, AND INTENSITY.

The penetrating ability of an X-ray beam is called its "quality." It is usually arbitrarily measured by the thickness of aluminum which will permit the same intensity of radiation to pass through it as passes through a standard thickness of silver. Equality of intensity is determined either by means of the illumination of a fluorescent screen or by the blackening of a photographic plate. There is no experimental evidence that measurements of the same beam made in the two ways will agree, but it may be possible that some fluorescent screen may be found which will have the same effect as some particular photographic plate.

There are several methods in use for measuring the quantity of radiation passing a given point in a given time. Among these are:

- (1) Precipitation of iodine from its solution in chloroform.
- (2) Precipitation of calomel from a mixture of ammonium oxalate and bichloride of mercury.
- (3) Change in color of barium platino-cyanide.
- (4) Total ionization produced in air by the rays.
- (5) Density of blackening of a photographic plate.
- (6) Heating of a bolometer.
- (7) Change in resistance of a selenium cell.
- (8) The quantity of radiation is taken as proportional to the product of the P. D. across the tube, the current through the tube, and the time.

The first method has the objection that X-rays are not the only means of causing the precipitation. In method 2 a fresh solution must be employed for each reading. In spite of the fact that method 3 is open to the same objection as method 1, it has

met with some favor, and there are numerous types of dosage-meters based on this principle, each with its own scale of tints. Tables have been published (for instance, in *Arch. d'Elect. Med. du Bordeaux*, July, 1910) by which readings taken on any of the arbitrary scales of the above three methods may be converted into the reading on any of the other arbitrary scales, but the scales in method 3 are only accurate for rays within some definite range of hardness. These three methods have the great advantage that they record instantaneously the quantity of radiation absorbed by the instrument, and may, therefore, be used as dosage-meters. Method 4, although it may be made very exact and although it is excellent from the point of view of the physicist, is unsuited to the requirements of the physician, in that it can not be well used in the summer. It has not been checked against the other methods. If the hardness of the tube and the kind of plates and method of their development are specified, method 5 is useful in cases where it is not necessary to shut off the tube as soon as a certain quantity of radiation has been given off. Methods 6 and 7 have not as yet found much favor. They have not been checked against the other methods. Method 8 is entirely empirical for each apparatus, and a change in any part of the outfit necessitates a new calibration. Although a given operator may use this method with his particular outfit, he cannot easily compare his data with that of another operator having an outfit which differs from his own in any respect.

Intensity has been measured in three ways:

(1) Variation of distance from the tube (all other conditions being unchanged).

(2) Brightness of a fluorescent screen.

(3) Quantity per second (measured by any method given in the previous paragraph).

Method 2 can not be used to compare heterogeneous beams of different compositions (see page 293), and as a result is not accurate when used to compare the rays given off by a tube at one time with the rays given off by the same tube at another time under even slightly different conditions. Method 3 is open to the advantages or disadvantages of the particular method employed to measure quantity.

ON THE THEORETICAL EFFICIENCY OF THE LINDE PROCESS OF LIQUEFYING AIR.*

BY

M. M. GARVER, B.S.,

Associate Professor of Physics, Pennsylvania State College.

NOTWITHSTANDING the voluminous literature on the subject of the liquefaction of air, I fail to find what seems to me a really satisfactory exposition of its theoretical features based on fundamental thermodynamic facts and laws. Some important theoretical points are either unnoticed or only incidentally touched on,—*e.g.*, the fundamental influence of molecular attractions on the possibility of liquefaction at all; and, more particularly, the peculiar rôle molecular attractions play in a continuous isothermal process, where all the heat abstracted from the compressed air is confined to what is given out at readily available temperatures such as is afforded by the ordinary water supply. For instance, in Poynting and Thomson's *Heat*,¹ the authors of which may be regarded as occupying positions of the highest authority on any subject to which they give their attention, the cooling in such process is merely incidentally attributed to the work done in overcoming molecular attractions; and the reasons for the statement are given only by calling attention to an apparent analogy of the process to that of the porous plug experiment. From this fact I conclude that probably no more satisfactory, concise, and non-mathematical explanation was known to them or it would have been given, or at least referred to. A more complete theoretical explanation *may* have been published, but, if so, I also am unacquainted with it. I know of no more satisfactory, concise explanation of the theory than they offer; but, in my judgment, their exposition is too brief and incomplete to enable one to comprehend the process as a whole. Other writers, again, attribute the cooling to work done on the gas by itself. While this statement is true, in a sense, it may be misleading, because in the continuous process work is continually

* Communicated by the author.

¹ 3rd ed. (1908).

done *on* the gas as well as *by* the gas; and part of the work done by the gas goes to heat it. The part of the work which does not produce heat consumes heat and produces the cooling. In general, the theory seems to be derived from the workings of the apparatus rather than the converse of designing an apparatus to fulfil certain theoretical conditions.

The difficulties met with in trying to form a clear judgment, based on fundamental thermodynamic conceptions, of the regenerative process as applied to the liquefaction of air, and of the relation of this process to the porous plug experiment, lead me to think that the theoretical results at which I have arrived may be of general interest.

All the early attempts at the liquefaction of gases were made with a definite quantity of gas, and the result, when successful, could in many cases be attributed to the doing of *external* mechanical work by the gas after it had been sufficiently compressed and cooled. Hence the impression is apt to linger in the mind that by some process,—by some mechanical appliance,—the air in the continuous process should be made to do external mechanical work during expansion in order that it may be cooled thereby and a larger output of liquid obtained. In fact, one of our best text-books on general physics makes the definite statement that if the compressed air were expanded against a moving piston so as to do mechanical work a larger supply of liquid air might be obtained. Another standard work represents the expanded and cooled air as passing a *second time* through the pump and cooler, so that the operation may be repeated and the effects accumulated. Now it seems to me that if the correct theory were known and published such statements would not be made, for they are not in accordance with thermodynamic theory. But without some guiding theoretical principle one is apt to be over-impressed when comparing the 24 calories of the litre-atmosphere unit of work with the slight cooling effect, of about one-fourth of a degree centigrade per atmosphere in the expansion of air noticed by Joule and Thomson in their celebrated porous plug experiment. Yet it may be shown from general principles, without reference to special apparatus, that this slight cooling effect, in so far as it represents internal molecular work in the form of a displacement against a resistance (molecular attractions), is the sole source of the cooling during an “isothermal” continuous

process. The "isothermal" case is the general case and is theoretically the most interesting. Of course, special refrigerants may enable us to liquefy a larger percentage of the compressed air; but the two processes, considered as one, will be less efficient than the simple isothermal process, as may be seen in the sequel.

It is not the present purpose to discuss the general theory of refrigerating processes further than necessary to show in a general way the difference between a continuous process leading to the liquefaction of a portion of the gas operated on and one adapted to the production of a moderate cooling of a large mass of material. In the latter case both external and internal work may be utilized; in the former only "internal" work. A correct theory of the continuous liquefying process will disclose the scientific reasons for the difference in practice in the two cases of refrigeration and liquefaction, and will aid in designing the apparatus for a given purpose. The experimental basis of the theory of liquefaction by a continuous process is the famous porous plug experiment, while the continuous refrigerating process utilizes the heat of vaporization of a volatile liquid. In the cooling and ventilating process the cooling is mainly due to the external work done by the expanding air.

THE POROUS PLUG EXPERIMENT—PRELIMINARY CONSIDERATIONS.

In the usual discussion of a gas, escaping into a vacuum, no details are given, but merely the simple conclusion, confirmed by experiment, that because no external work is done the energy, and consequently the temperature, remain unchanged. But evidently the introduction of the first increment of gas into a vacuum produces a pressure, and each successive increment meets the pressure caused by the earlier portion. Since the gas is indefinitely expansive, we may regard each increment as filling the whole space, or volume; hence the work is simply

$v \int_0^2 dp = pv$. But this is equal to the kinetic energy of the gas, so that in this case all the work done while forcing in the later portions of the gas against the existing pressure is transformed into the kinetic energy pv . If no change of temperature occurs, we may say that, in this case, the work done *by* the gas is equal to the work done *on* it.

In the general case of a fluid, compressible or incompressible, the external work required to transfer the mass m from a region of steady pressure p_1 to another region of steady pressure p_2 will be equal to $m \left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1} \right)$, the subscripts representing the two states respectively. For since each pressure is constant the work done *by* region *one* must be equal to $p_1 v_1$, and the work done *on*, or *in*, the region *two* must be equal to $p_2 v_2$. The difference, whether positive or negative, represents the external work done and supplied from outside. Since $m = \rho v$, where ρ is the density and v is volume of the mass m , we may write $\frac{m}{\rho}$ for v , or

$$w_2 - w_1 = w = m \left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1} \right).$$

We may note three cases: *First*, when there is no change in density, or the fluid is an incompressible liquid, and $w = \frac{m}{\rho} (p_2 - p_1)$. *Second*, when the density is strictly proportional to the pressure, in which case the parenthesis $\left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1} \right) = 0$ and no work is done, or, $p_2 v_2 = p_1 v_1$. In the *third* case, however, the external pressure may be diminished by internal attractions depending upon the distance apart of the molecules, so that when $v_1 < v_2$ then $p_1 v_1 < p_2 v_2$, when the temperatures are equal, or the external work done *on* the gas is no longer equal to the external work done *by* the gas, because a part of the energy is used during expansion in doing *internal* work in separating the molecules.

In the text-books and in the various discussions of the porous plug experiment much attention is given to the work done on and by the gas. But by considering only "steady" states and a constant stream with "steady" pressures and temperatures, with no energy in any form entering or leaving the stream at any point, the case in nowise differs from the transmission of energy in the direction of its length by a rod whose state of strain is steady, when it is perfectly evident that the rod transmits without loss what is impressed on it, both as to force and displacement. The same is true of a belt whose state of strain is steady, except that a "pull" replaces the "push." Likewise, when the temperature and pressure of a gas, in a given volume of gas, are kept constant while additional gas is being forced in, the stress

introduced by the entering gas must be relieved at some point by the escape of an *equal* amount, or the temperature and pressure would be changed. The work done *by* the escaping portion must, by the law of conservation, be equal to the work done *on* the gas if the state of the gas is *steady*, just as in the cases of the rod and the belt.

THEORY OF THE POROUS PLUG EXPERIMENT.

Consider an enclosed space, or chamber, A , into which gas is being forced by a continuous steady pressure, isothermally (that is, through a cooling device which keeps the temperature constant). Now suppose that when the pressure in A has reached a certain value the gas escapes into another and larger chamber, B , through a constant pressure valve, or other device, as in the porous plug experiment, and that likewise the gas escapes from B at a pressure much lower than that at which it escapes from A into B . (The pressure in B may be the atmospheric pressure.) Now if no heat or other form of energy enters or leaves the compartments *except as carried by the gas* from A into B , we shall, after a time, have a "*steady state*" throughout the whole system. Whatever the temperatures and pressures in the two compartments may be, after the state becomes steady, *the energy per unit mass of the gas must be the same in both A and B* . We need make no assumptions as to the applicability of Boyle's law, for the same stream, and therefore the same mass of substance and the same quantity of energy, are passing through both at the same rate; and in both compartments both are receiving the same quantity and both are giving out the same quantity without changing the steady temperature and pressure. Since the volume of each chamber is constant, any change in the total energy in either A or B implies a corresponding change in the temperature, pressure, volume, or density; but these are assumed to be steady, or unchanging. Therefore, if we represent the total energy per unit mass by E , then $E_1 = E_2$, where the subscripts represent the compartments A and B respectively. But, since the energy in each case may consist of kinetic and potential energies in different proportions, we may write $E_1 = k_1 + w_1$, and $E_2 = k_2 + w_2$, or $k_1 + w_1 = k_2 + w_2$, where k represents kinetic and w the potential energies.

Experiment shows that the specific heat of a gas is nearly

independent of temperature and pressure, provided it is so determined as to be independent of the work done on or by the gas during the necessary change of temperature. Therefore, if the heat of a gas is proportional to the kinetic energy of the gas, we may write

$$\frac{H_2}{H_1} = \frac{T_2}{T_1} = \frac{k_2}{k_1}$$

where T represents the absolute temperature. These ratios may also be written

$$\frac{T_1 - T_2}{T_1} = \frac{k_1 - k_2}{k_1} = \frac{w_2 - w_1}{k_1}$$

since $k_1 - k_2 = w_2 - w_1$.

In the case of atmospheric air, Joule and Thomson's experiment showed that $T_2 < T_1$, hence that $w_1 < w_2$, or the potential energy diminishes with the volume. Amagat's experiments on the isothermal compression of air show that $p\bar{v}$ decreases with the volume for values of p less than 75 atmospheres. From these two experimental results we may conclude that the internal attractions aid appreciably in diminishing the external pressure p in the case of air.

Let us now examine the influence of this molecular attraction during the isothermal compression and subsequent expansion, during which the gas does internal work on itself, and the escaping portion is reheated, notwithstanding the internal work it does in overcoming molecular attraction during the expansion.

When an amount of external work W is done on a gas, compressing it isothermally, the internal attractions, if they exist, will supply a quantity of internal work w which will also be abstracted as heat. The total will be $W + w = H_1$ (say), the total heat taken from the gas during isothermal compression. Now since the heat equivalent of the total work, $W + w$, has all been taken away, the total energy per unit mass of the gas has been diminished by the amount w . Hence, if the gas by any process whatsoever be allowed to expand without receiving energy in some form from outside sources, the internal work w will have to be done; and the heat equivalent of that work, if obtainable from no other source, will be taken from the kinetic energy of the gas itself, with a resulting fall in temperature. If w represents the heat abstracted from *one* gramme of the gas, producing a temperature drop, t , in the whole mass, then if taken from one-half

of the gas the temperature drop will be $2t$; and if taken from the n^{th} part, nt degrees, if the specific heat is uniform. Hence it is plain that if this temperature difference can be maintained in such manner that the warm, compressed air can be made to warm the cooler expanded air so as to return it to the atmosphere at its original temperature and pressure, a portion of the substance, for lack of energy, must perforce, remain behind in the apparatus. Let us, therefore, introduce a slight, but important modification in the arrangements of the two compartments, A and B , described above, keeping the other features unchanged. Suppose the compartment A to consist of a long copper tube, or other good conductor of heat, and that B is a concentric non-conducting tube, so that it is free to receive heat from A but none from outside sources. At the beginning of the process an abrupt, or sudden, change of temperature will occur at the point where the pressure changes. Since the expanded air is always cooler than the compressed from which it issues, and the two are separated only by a thin conducting partition, the compartment A will *at first* give out energy *faster* than it receives it; but this state of affairs can not continue indefinitely. It will cease and become "steady" when the heat of liquefaction occurring in A will limit its output to its intake. If perfect heat insulation were possible, the condition of maximum efficiency would require that the escaping air be restored to the atmosphere at its original temperature and pressure. For, if the air leaves the apparatus at any lower temperature than this, all the heat that might have been abstracted has not been carried away, hence the possible amount of liquid would be diminished.

It has been shown that if the w units of heat abstracted from one gramme, and causing a drop of t degrees, could be concentrated on the one- n^{th} part of the mass it should cause a drop of nt degrees. Assuming that the specific heat is uniform and constant and independent of the volume, we may make an estimate of the quantity of liquid obtainable with a given compression. From Amagat's, and other experiments the product pv for air is a minimum at about 75 atmospheres, and does not exceed normal values for pressures less than 150 atmospheres. Let us take 160 atmospheres for convenience. We may take the specific heat at constant volume as .177. The heat of vaporization is given as 50 calories per gramme. Hence, to lower the temperature of a gramme of air from 20° C. to -190° C., or 210° , will supply 210

$\times .177$ calories,—*i.e.*, 37 calories. Hence, to cool and liquefy one gramme under the given conditions would yield 87 calories. According to the Joule and Thomson experiment, the cooling is $\frac{1}{4}$ degree per atmosphere, or 40° C. for 160 atmospheres, indicating 7 calories per gramme. But since 87 calories must be abstracted, under the given conditions, then, if the apparatus is perfect, between $1/12$ and $1/13$ of the whole mass should be liquefied.

The question still remains: Could not a larger output be obtained by making the compressed air do external work while expanding against a moving piston?

Theoretically, the maximum effect can be produced only when the process is reversible. The maximum amount of work, and hence the production of the maximum drop in temperature, requires that the expansion be adiabatic; but the data are not very reliable over such a wide range of temperature and pressure. The formulas apply only to gases, but as a substance approaches liquefaction it becomes properly a vapor and the formulas mere approximations. If, however, we apply the formula $\int_1^2 p dv$ to the adiabatic expansion of air from 160 atmospheres to 1 atmosphere, we get from

$$\int p dv = - \frac{v_0 p_0^{\frac{1}{k}}}{k} \int_{p^{\frac{1}{k}}}^{160} \frac{dp}{p^{\frac{1}{k}}} = 303.5$$

litre atmospheres, or 7275 calories from 200 grammes of air (one litre at 160 atmospheres) at 20° C. This is less than 37 calories per gramme, the amount required to lower the temperature to the boiling-point, or liquefying temperature at atmospheric pressure, without producing any liquefaction. Practically the same result is obtained by applying the formulas for adiabatic expansion and temperature change for a pressure change from 160 atmospheres at 20° C. to 1 atmosphere at T degrees absolute. The resulting temperature is found to be 67° absolute, which is only 10° below the normal boiling-point of nitrogen. This gives only about 1.8 calories per gramme toward liquefaction, which requires 50 calories per gramme. The two results agree as well as could be expected, in consequence of the uncertainty in the value of the specific heat used, 0.177. The value of k used was 1.41.

In any case, perfect heat insulation and perfectly reversible adiabatic expansion would be required to obtain *any* liquid at all by the doing of external work, if the compression does not exceed 160 atmospheres at 20° C. Of course, if the pressure were reduced below one atmosphere, a larger change in temperature could be produced. But such procedure would require the application of work from the outside and would cut down the efficiency. Since air costs nothing to procure, the maximum efficiency is reached when the ratio, $\frac{\text{Liquid obtained}}{\text{Work done}}$, is a maximum.

The reason of it becomes plain when we reflect that *combined* pressure and low temperature are the important elements in the liquefaction of a gas. By the expansion while doing work one important element, the compression, is nullified. It is impossible to do work and retain the compression.

It was shown in a preceding paragraph that, from the temperature relations, ideal conditions should permit of about 1/13 of the air being liquefied with 160 atmospheres compression at 20° C. It may be of interest to express this relation in terms of the work done by the interior molecular attractions.

Since the rejected air is assumed to have the same temperature and pressure as the original, the ratio of the energies will be the same as the ratio of the masses. Let M_1 represent the initial mass and M_2 the rejected mass, H_1 and H_2 the heat equivalents of the work W and w , respectively, where W represents the external work done during isothermal compression and w the internal work of molecular attraction. Then we must have

$$\frac{M_1}{M_2} = \frac{H_1 + H_2}{H_1} = \frac{W + w}{W} \text{ or, } \frac{M_1 - M_2}{M_2} = \frac{w}{W} = \frac{L}{M_2}$$

where L represents the mass of the liquid. Or, the ratio of the liquid mass to the mass of the rejected air is in the same proportion as the work due to the molecular attractions is to the external work done during isothermal compression. We may test this relation, using the same data as for adiabatic expansion,—*i.e.*, 160 atmospheres and 20° C.

We found previously that the experimental value of ¼° per atmosphere indicates 7 calories per gramme internal work. For 200 grammes (as before) the value of $w = 1400$ calories. Now, to compress 200 grammes *isothermally* would require 818 litre

atmospheres of work, or 19,600 calories. This is exactly 14 times 1400, or, the ratio $w/W = 1/14$. This, under the circumstances, may be regarded as a very fair agreement. At all events, molecular attractions are not a vanishingly small quantity if they do $1/14$ of the work during isothermal compression, and correspondingly oppose adiabatic expansion.

STATE COLLEGE, PA., December 30, 1913.

The Bleaching Action of Hypochlorite Solutions. S. H. HIGGINS. (*Chem. Soc. Proc.*, xxix, 302.)—Bleaching powder solution to which an excess of boric acid has been added has very energetic bleaching properties, because the boric acid merely liberates hypochlorous acid from the hypochlorite, whereas an excess of hydrochloric acid produces free chlorine and a solution of very weak bleaching properties. If, however, calcium carbonate be added to the latter solution, hypochlorous acid is regenerated, and the bleaching properties are restored. The addition of hydroxides to hypochlorite solutions opposes the hydrolysis of the hypochlorite, and retards the bleaching action, whereas the addition of small quantities of acids assists the hydrolysis and stimulates the bleaching action; the effect on the bleaching properties of the solution is due to the active mass of the free hypochlorous acid present, but in the one case reduced and in the other augmented. Even in the presence of a large excess of hydroxides the solutions have little bleaching effect, which is probably due to a small amount of hypochlorous acid being still present in solution in spite of the opposition of the hydroxide to the hydrolysis of the metallic hypochlorite. All the experiments point to the conclusion that hypochlorite solutions owe their bleaching properties to the free hypochlorous acid present in solution. Sometimes there is a secondary reaction between the hypochlorous acid and any neutral chloride present, producing nascent chlorine of energetic bleaching properties, but the main action is one of direct oxidation by the hypochlorous acid. If chlorides are produced, their stimulating effect on the bleaching action is negligible.

Conductivity of Copper. ANON. (*Brass World*, x, 1, 10.)—The electrical conductivity of copper depends on the total amount of impurities and not upon any one element. This is why the conductivity test is so valuable in determining the purity of copper. The total of all the impurities is shown, and thus the purity of the copper is indicated. Amounts of impurities that will defy detection by chemical analysis are found when the electrical conductivity test is applied. It is, therefore, one of the most valuable tests known to metallurgy.

HIGH PRESSURES AND FIVE KINDS OF ICE.*

BY

P. W. BRIDGMAN, Ph.D.,

Jefferson Physical Laboratory, Harvard University.

THE experiments which I am about to describe are experiments in the field of very high pressures, which is a practically new field. Under conditions of high pressure, many of the ordinary properties of matter are changed; and the bursting strength of vessels in which such pressures are produced is found to bear no relation to their strength under ordinary conditions. In conducting the following investigations on the effect of very high pressures on water, it was found necessary to make many preliminary experiments on the strength of the containing vessels before accurate measurements of pressure could be made. In the course of this preliminary work many interesting facts concerning the behavior of materials under high pressures were disclosed. In this paper will be given, firstly, some of the results of the preliminary experiments on the strength of the containers, and then a description of the experiments made to ascertain the effect of high pressures on water. The paper will be, in large part, a record of my own experimental work.

By way of introduction, it is perhaps desirable to give some idea of the magnitude of the pressures involved. The highest pressures which are ordinarily familiar to us are probably those of modern high-power artillery; the average firing pressure exerted in many of our large guns is about 2000 atmospheres, or 30,000 pounds per square inch. The highest pressures reached in the experiments which I am about to describe are ten times this amount; that is, 20,000 atmospheres, or 300,000 pounds per square inch. A pressure of 20,000 atmospheres, if exerted against a rod of steel one inch square, would enable it to support a locomotive weighing 150 tons. The highest pressure I know of that has been previously measured is 10,000 atmospheres; this was produced by the explosion of nitroglycerin in a closed vessel; it is about one-half the pressure recorded in the present experiments.

* Abstract of paper presented at the meeting of the Section of Physics and Chemistry held Thursday, November 13, 1913.

Nitroglycerin subjected to the pressures attained in the following experiments would lose all ability to explode. The pressure exerted at the bottom of the ocean at, say, a depth of six miles is about 1000 atmospheres; a pressure of 20,000 atmospheres would, therefore, be exerted at the bottom of an ocean 120 miles deep. If the average density of the rocks of the earth's crust is taken as 2.5, 20,000 atmospheres is the pressure which prevails at a depth of fifty miles below the surface of the earth.

It should be borne in mind that in all the experiments made the pressures were produced in a liquid, which must be held in a container. It is a comparatively simple matter to produce pressures as high as 300,000 pounds per square inch in a solid piece of steel, but it is another matter to maintain such a pressure in a liquid and prevent all leaking of the latter from the container.

The most essential part of the preliminary work was to design a packing that would keep the vessel in which the pressures were to be produced absolutely tight, and prevent the liquid from leaking from it. The feature of the form of packing finally designed is that it is made tighter and tighter by the pressure in the vessel itself; the greater the pressure obtaining in the vessel, the less can the liquid leak. Most of the packing in ordinary use is made tight by compressing it by means of a screw; a packing so compressed will leak as soon as a pressure is exerted on the liquid it holds back equal to that initially produced on it by the screw; further, the pressures that are here dealt with are much greater than any pressures it is possible to produce by such means. The ordinary screw-tightened packing is, therefore, always certain to leak. With a packing that tightens itself by the pressure in the vessel, however, the only limit to the pressures that can be reached is set by the strength of the vessel itself.

The second part of the preliminary work consisted in finding what limits of pressure a steel vessel will support, steel being selected as the best material of which to make the container. In all the experiments the pressures were produced by pushing a piston, by means of a hydraulic press, into the cylinder containing the liquid, and this means of producing the pressure immediately introduces two essentially different problems. The first is the consideration of the strength of the steel piston, and the second that of the strength of the steel cylinder. These problems are independent, as these two parts of the apparatus

are subjected to different strain. In the piston the strain is one of compression, while in the cylinder it is one of bursting, or tension.

It was found by experiment that the best material for the piston was glass-hard steel. A steel that is left glass-hard is usually too brittle to use, and its temper has to be drawn, but this process makes the steel a little softer, so that it will not support so high a compression as when left glass-hard. Under the conditions in the experiments the piston was subjected to a direct compression, without any tendency to bend, so that its brittleness, which would be detrimental under conditions of compound stress, was not here objectionable. Steel from many different manufacturers was tried, and the best grades of steel for this purpose were found to be steels which contained some chromium as well as high carbon. The compression that a piece of glass-hard steel will support when it is held rigidly so that it will not bend is surprisingly large; several grades of steel were found that would support a compression of 600,000 pounds per square inch, and one grade supported as high as 750,000 pounds per square inch. It will be noticed that these pressures are about twice as great as the highest pressures recorded in the present experiments. The problem of the strength of the piston did not, therefore, prove of difficulty.

The strength of the steel cylinders was also a factor which had to be settled by experiment, since it was found that no theory of the strength of a cylinder is of any value for very high pressures. All ordinary theories predict that no cylinder can be stressed to more than the tensile strength of the steel, no matter how thick are its walls; thus if the tensile strength of the steel is 150,000 pounds per square inch (as it is for many grades of high carbon steel), then theory predicts that it is impossible to maintain a pressure of more than 150,000 pounds per square inch in a cylinder, even with infinitely thick walls. It is, however, of no particular use to make a cylinder of more than a certain thickness, for the reason that the inside layers support most of the pressure; the outside layers of the material of a very thick cylinder do not take up the stress of the inner layers, and the cylinder flows at the inside at a certain pressure. A few rough experiments showed the actual pressure that a cylinder can support to be much in excess of that predicted by the ordinary

theory; this is on account of the fact that when the pressure reaches a certain value the inner layers do not break, but stretch, and thus allow the outer layers to assume some of their share of the load. It was found that the most efficient way to make a cylinder support a high pressure was first to stretch it on the inside by applying a much higher pressure than it was intended to maintain in practice, and then to machine it to its final diameter. A cylinder treated in this way is in a state of internal strain, exactly as is a gun which has hoops shrunk on it from the outside, the tension in the hoops inducing initial compression in the interior of the gun. When pressure is produced in such a gun, it removes the compression from the inner layers of the material and the tension of the outer layers is increased. But it has been shown that the tension in the inner layers increases more rapidly than that in the outer, and it can be seen, therefore, that, in time, the increasing tension in the inner layers neutralizes the compression which existed there initially and eventually equals the increasing tension of the outer layers, with the result that finally the stress throughout the mass of the cylinder is one of uniform tension. In an ideal condition all parts of the cylinder would be ready to break at the same time, and then the maximum possible strength would result; in any actual case it is, of course, impossible to reach this ideal, but, with the cylinders subjected to a preliminary stretching, it can be approached much more nearly than even in a built-up gun. There are other considerations, which need not be gone into here, which come into force when the cylinder becomes very thick. In actual practice, as already stated, very little is gained in making the cylinder of more than a certain thickness.

The best steel to use for the cylinder is found to be a steel which will stretch considerably before breaking, but which has, at the same time, a high tensile strength. The glass-hard steel used for the piston would not serve at all for this purpose, as a cylinder made of such material would inevitably crack at the inner layers, instead of stretching, and so would not allow the outer layers to assume their share of the load. The steels found most suitable are those tough steels that have been put upon the market to meet the demands of the manufacturers of automobiles. One steel made by Krupp was found very good, but best of all was a steel made in this country by the electric fur-

nace method; this steel is a chrome vanadium steel, and has, when hardened in oil, a tensile strength that may reach as high as 300,000 pounds per square inch. The highest pressure that I have ever found it possible to reach in a cylinder has been 40,000 atmospheres, or twice the highest pressures at which I have made accurate measurements.

In the preliminary work on steel cylinders many cylinders were broken. This gave opportunity for interesting observations on the manner of rupture at high pressures, and two facts not to be expected according to ordinary theories were noted. The first was the enormous amount of stretch that the steel at the inner layer of a cylinder will support without rupture; this is well shown in Figs. 1, 2, and 3. In the first figure the cylinder

FIG. 1.



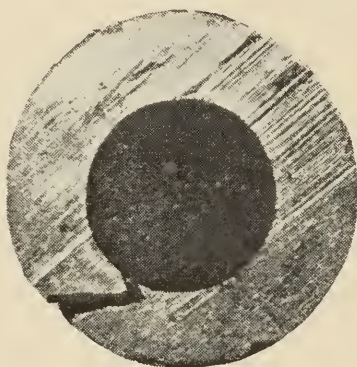
One of the halves of a cylinder of tool steel split by the application of internal pressure. The inner hole has stretched from $\frac{1}{2}$ inch to $1\frac{1}{5}$ inches. The maximum pressure withstood by this cylinder was 30,000 atmospheres.

was originally one-half inch in diameter, but it stretched to one-and one-fifth inches before breaking. This same specimen of steel, if tested for tensile strength in the ordinary way, would have broken when the strain had become about 30 per cent., whereas here the strain was about 140 per cent. before the rupture took place. The second observation was that in all the cylinders tested the break started at the outside, where the stress and the strain are both least; this was observed in all the steels used. There is reason to believe, however, that very brittle substances like glass would break at the inside, as predicted by the ordinary theory. The fact seems to be that if the substance is brittle it will break at the inside first, but that if it is at all plastic it will break at the outside first, the crack travelling into the inside.

In addition to the data obtained regarding the manner in

which materials break at high pressures, many other peculiar facts were noted during these preliminary tests. Perhaps the most interesting of these is the increase in rigidity experienced in substances ordinarily soft and pliable. A striking example

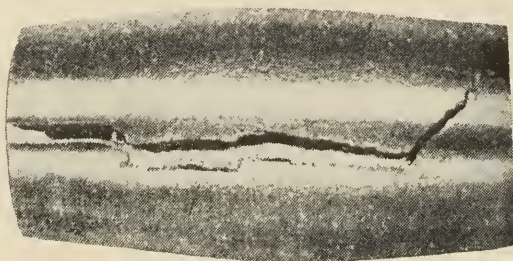
FIG. 2.



Cross section of a cylinder of Bessemer steel ruptured by the application of internal pressure. This cylinder was originally 2 inches outside and $\frac{1}{2}$ inch inside diameter. The inner hole has been stretched to $1\frac{3}{8}$ inches.

of this is afforded in the case of paraffin, which under pressures as high as 20,000 atmospheres becomes more rigid than soft steel, so that if paraffin is forced to flow by the application of a very high pressure, and a piece of soft steel is imbedded in it, the steel will flow with the paraffin and will become distorted and twisted with the latter. Soft rubber also becomes very hard

FIG. 3.



View of the outside of the cylinder shown in Fig. 2, taken before the section was made.

and brittle under high pressure; in one experiment a soft rubber washer became so brittle that it cracked like glass, and a soft steel washer in contact with the rubber was forced by the pressure in ridges into the cracks in the rubber, thus showing that the rubber had become harder than the steel.

At the beginning of the experiments it was feared that the steel of the cylinder might become porous under very high pres-

sure, causing the liquid to be forced through the solid walls. No instances were found, however, in which the liquid had been forced, by pressure, into the solid metal to any appreciable depth. Many instances have occurred in which a liquid has been blown in a solid stream through apparently solid steel, but all such cases have been traced to flaws in the steel. The only apparent exception is the impossibility of retaining mercury in a cylinder under a high pressure, as the mercury invariably finds its way through the walls and usually ruptures the cylinder. The explanation of this was found to be, however, that the mercury amalgamates with the steel under high pressure, so that this is properly a case of porosity.

Another all-important task in the preliminary experiments, in addition to that of finding what pressures the steel vessels could stand, was to devise some way of accurately measuring the pressure. It need hardly be said that none of the ordinary pressure gauges are of the slightest service at these high pressures, and some means of measuring pressures other than with an ordinary gauge had, therefore, to be devised. The very simplest method that can be conceived proved to be the best in this case. It consists in inserting a steel piston through a hole in the wall of the cylinder and measuring the force necessary to prevent it from being blown out by the pressure within. There are many mechanical difficulties in realizing such a method as this, the most obvious being to overcome leakage. To do this the piston must fit the hole tightly, but at the same time must fit so freely that there is not enough friction to destroy the accuracy of the readings obtained by its means. It was found possible, by using a small-diameter piston fitting into a comparatively long hole, to take care of both these factors. With the gauge as finally constructed, pressures up to 13,000 kilogrammes per square centimetre were measured with an accuracy of one-tenth per cent. After high pressures had been successfully measured with such a gauge, it was found possible to construct gauges of a much more convenient form for actual use, and to calibrate them against this, which became an "absolute" gauge. One gauge that I have used in most of my later work is a manganin resistance gauge, which consists of a coil of manganin wire placed in the pressure cylinder and connected through insulated leads with apparatus for measuring the resistance. The electrical re-

sistance of this coil is found to change with changes of pressure in the cylinder. In the case of manganin, the resistance increases as the pressure increases, and by comparing with the absolute gauge the increase was found to be almost exactly proportional to the increase of pressure. On account of this, manganin is a very much more convenient material to use than any pure metal, since the resistance of all pure metals decreases as the pressure increases, and the decrease is, moreover, not proportional to the increase of pressure.

After the completion of the preliminary work, in which the methods of producing and accurately measuring high pressures had been decided upon, there were opened a number of interesting fields for investigation, and the question arose as to which field to choose in order to obtain the most significant results. It was at once seen that nearly any kind of measurement would involve, as one of the data needed in discussing the bearing of the results, a knowledge of the change of volume of the substance under pressure, with the pressure, and it was decided, therefore, to obtain, first of all, measurements of such changes or compressibilities.

The first substance chosen for the measurement of compressibility was water, chiefly as it is so common a substance, and because many measurements had been made on it previously at low pressures. In this connection a method was devised by which the compressibility of water could be measured up to 12,000 kilogrammes. It will be well to mention here that water is not absolutely incompressible, as is commonly supposed, but that its volume may be very appreciably diminished by the application of sufficiently high pressures. Under 12,000 atmospheres a decrease of volume of about 20 per cent. is produced. The measurements of the compressibility of water by the new method were found to be satisfactory at comparatively low pressures, but at higher pressures there were, quite frequently, discrepancies which could not be explained by errors in the apparatus. The temperature of these measurements was that of the room, about 20° C.

Apparently the only possible explanation of the irregularities shown was that the water had been frozen by the high pressure, so that measurements of the volume at high pressures were sometimes being made on the liquid and sometimes on the solid.

This explanation, if it were the true one, indicated a very remarkable state of affairs, as the application of ordinary pressures to ice causes it to melt. One would expect to be able to melt ice by high pressure, therefore, and not to freeze water. However, the above explanation does not seem so utterly improbable as this reasoning would suggest, when there is taken into consideration some remarkable work performed by Professor Tammann at Göttingen. Professor Tammann found that when ice is subjected to pressure at temperatures lower than -22° C. it is no longer possible to cause it to melt, but that, instead, it changes in form, passing over to another kind of ice which is more dense than water, instead of less dense, as is ice at atmospheric pressure. The pressure needed to produce this second kind of ice is about 2200 kilogrammes per square centimetre. These two forms of ice are comparable to the two forms of carbon-coal and diamonds, with this difference, however: this new kind of ice changes to ordinary ice just as soon as the pressure on it is removed, in the same way that ordinary ice will change into water when a sufficient amount of heat is applied. Tammann succeeded in discovering two new kinds of ice, each denser than water.

The discoveries of Tammann materially assist in providing an explanation of the irregularities found in the compressibility measurements referred to above, since, if the ice is denser than water, it may be expected that its freezing point will be raised as the pressure is increased, according to the following reasoning: First consider ordinary ice,—that is, ice at atmospheric pressure; apply pressure to it, and its volume decreases slightly. But if the ice melts, its volume also decreases. Consequently, when pressure is applied, the ice is being helped to melt, so that ice under pressure will melt at a slightly lower temperature than does ice on which there is no pressure. In the same way, if the volume of the ice be less than the volume of the water, and pressure be applied to the water, its volume would be decreased, so that water under high pressure is frozen more easily than water at atmospheric pressure. In other words, if the ice is of less density than water, the freezing point is lowered by the application of pressure, but if the ice is of greater density than water, the freezing point is raised by pressure.

The application of this proposition to the irregularities men-

tioned above is immediate. Tammann had discovered that at high pressures there are two modifications of ice, each of which is denser than water. It would be expected that the freezing point of the modified form would be raised by the application of pressure, so that possibly the irregularities could be explained by the freezing of water to this new form of ice at 20° C. under the very high pressures reached in this work, which were about five times those reached by Tammann. But the fault in this explanation is that Tammann had predicted from measurements on this new kind of ice that no pressure, however great, could possibly raise the freezing point of water higher about -17° , and a temperature of $+20^{\circ}$ C. was here being employed. Careful investigation of the whole matter was therefore called for, and special apparatus had to be designed to attack the new problem.

To state that it is possible in the experiments to ascertain whether the water has frozen to ice or not may appear strange, when it is considered that the ice is enclosed in a cylinder and can never be seen, because as soon as the pressure is removed and the cylinder opened the ice immediately liquefies. As a matter of fact, this cannot be ascertained, except indirectly. When the water freezes to ice, there is a decrease in volume, and this is shown by a drop in pressure. Conversely, too, when ice melts to water the volume increases, which is indicated by an increase of pressure.

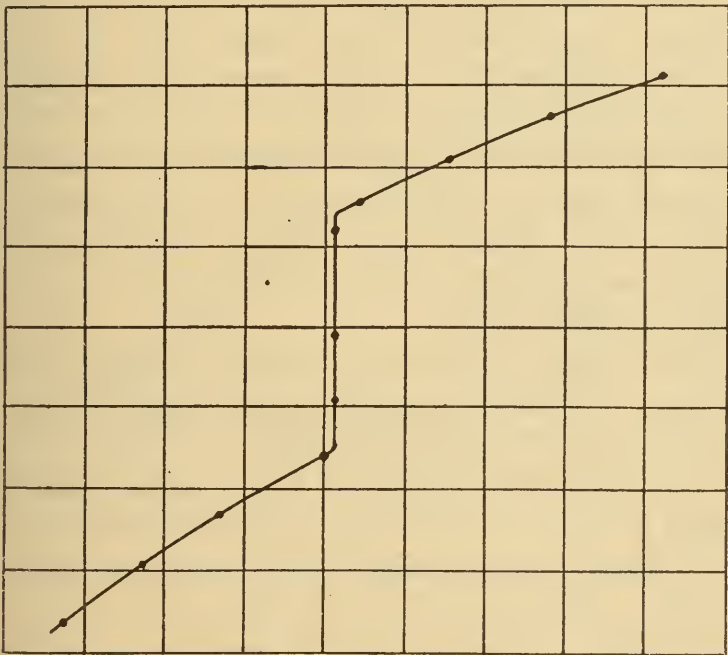
In the actual measurements the temperature of the water was kept constant. In order to increase the pressure, the piston was pushed into the cylinder, the distance being measured, and the displacement of the piston plotted against the increase of pressure produced. The pressure at first increased regularly as the displacement, but when the pressure reached a value high enough to freeze the water at the particular temperature of the experiment the volume suddenly decreased without the pressure rising at all. Then, after freezing was completed, so that there was only solid ice in the apparatus, the pressure resumed its regular rise with the displacement. This is illustrated by the curve in Fig. 4, in which the abscissæ represent pressures and the ordinates displacements.

The pressure at which the piston falls into the cylinder without producing a rise of pressure (that is, the vertical part of the

curve in Fig. 4) is the pressure at which the water freezes to ice at the particular temperature of the experiment. For every temperature, the pressure at which the water freezes is different. When the ice is denser than water, the freezing temperature increases as the pressure increases. In this way it is possible to find at what pressure water freezes for any given temperature, and so to construct so-called "melting curves."

It will be noted that the method given above, besides determining the pressure at which water freezes at a given temperature, determines another factor. The amount by which the pis-

FIG. 4.



ton is pushed in while the pressure remains constant evidently indicates the change of volume in the water while freezing, from which the difference in volume between the water and the ice can be computed. If we know the density of the water, we can calculate immediately the density of the ice. This is important data, since if both the temperature and pressure at which the ice melts are known, together with the change of volume, the amount of heat necessary to melt the ice can also be computed.

The method of experiment outlined above is not original with the writer, and has, in fact, been employed by many other previous experimenters. The only important difference is that the new packing which I devised makes it possible to obtain

a piston which has absolutely no leak, even at the highest pressures, and so renders possible accurate measurements of the change of volume. This has, I believe, not been possible before. In all previous experiments there has been some leakage around the piston, which made it impossible to obtain accurate measurements of the change of volume.

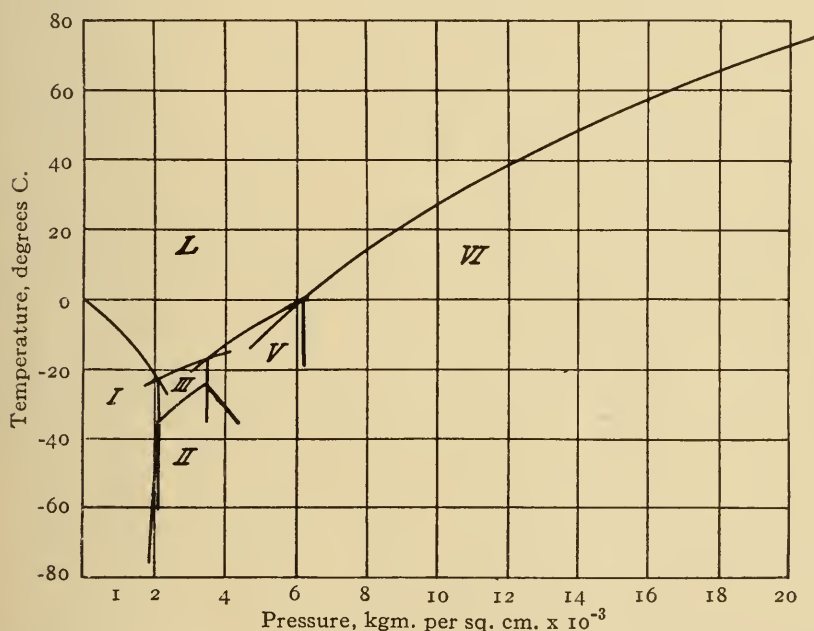
To return now to the compressibility measurements and the discrepancies found at high pressures, the application of the present method of experiment to the study of water showed that there did exist a new variety of ice at the high pressures, as had been suspected. It was found that the new variety of ice was not one of those two kinds previously discovered by Tammann, but was, instead, considerably denser than either of the varieties found by him. In addition to this new kind, which is stable at high temperatures and pressures, I discovered still another kind, not previously known, intermediate between the new high-pressure ice and the two varieties found by Tammann, making four varieties of ice denser than water. There are, therefore, in all, at least five different kinds of ice, only one of which we are ordinarily familiar with.

Fig. 5 shows more clearly the relation between these different kinds of ice. It will be noted that in this figure there are five regions, numbered according to the kind of ice to be found within the region. Thus, for example, if in an experiment the pressure be raised to 10,000 or 10^4 kgm. and the temperature maintained at 0° , these corresponding to the point 10, 0 on the diagram, the water substance will be found to exist in the form of ice VI. Or, again, if the pressure is 2000 or 2×10^3 kgm. and the temperature $+20^\circ$ (point on the diagram 2, 20), then the water substance is in the form of ordinary liquid water; or, thirdly, if the pressure is 1000 or 10^3 kgm., and the temperature -20° (point on the diagram 1, -20), then the water substance is in the form of ice I, the form we are ordinarily familiar with.

On any of the boundary lines of the regions in Fig. 5 the two adjacent forms of water substance are in equilibrium with each other, but if the state of the mass be changed slightly so that it is represented by a point within either of the regions, the kind of ice in that region prevails and the other disappears. Thus, let us suppose that there is ordinary ice, ice I, at say -10° and atmospheric pressure, in the apparatus at the beginning of

an experiment, then if the pressure be increased (keeping the temperature constant at -10°) at about 1000 or 10^3 kgm. (point 1, -10), the ice melts to water. But if now we continue to increase the pressure, at about 4400 or 4.4×10^3 kgm. (point 4.4, -10), the liquid water freezes again to a new kind of ice, ice V, which is denser than water. If we still further increase the pressure, at about 6300 or 6.3×10^3 kgm. (point 6.3, -10), the ice V suddenly changes to ice VI, the volume again decreasing during the change. Or, if we commence at atmospheric pressure and -30° (point 0, -30), and increase the pres-

FIG. 5.



The equilibrium diagram between the liquid and the five solid modifications of water.

sure, we first change ice I (ordinary ice) into ice III, then, on still further increasing the pressure, ice III changes to ice II; on further increase, II changes to V, and finally V changes to VI. The high temperature to which the curve between ice VI and the liquid runs is of interest; by the application of 20,000 or 20×10^3 kgm. we may freeze water, although it is nearly boiling hot.

The four varieties of ice denser than water have several interesting properties. Thus it will be noticed in Fig. 5 that the curve separating region VI from the region of the liquid, L, is prolonged into the region where V is stable. The interpretation of this is that it does not always hold that when one

of the modifications is carried into a region, in which another variety exists as the stable form, the unstable form will immediately disappear; thus it is possible to carry either liquid water or ice VI into the region in which V is the stable form, and to maintain it there for a considerable time without the change to V taking place. We are all familiar with a similar property shown by liquid water at atmospheric pressure; it is possible to cool liquid water considerably below 0° without the water freezing, particularly if care is taken not to subject the water to any mechanical disturbance. The fact that liquid water and ice VI may both exist in the region in which V is the stable form was the cause of considerable trouble during the first experiments, when it had not yet been established that there really was another form of ice, ice V. On the melting curve of ice VI below 0° a number of irregularities were found for which the only explanation seemed to be that there was a new variety of ice. At first, however, the experiments could not be repeated, and it was only after some time that it was discovered that an apparently very unessential variation was sufficient to determine whether VI or V would freeze out of water at temperatures a little below 0° . If the experiment was performed with the water contained in a glass bulb, ice V would freeze out of the liquid, but if the water was enclosed in a steel bulb, then ice VI almost always froze out of the water. The presence of a few splinters of glass was sufficient to ensure the appearance of V instead of VI. The explanation of this strange phenomenon has not yet been found. The phenomenon is simply an illustration of a fact with which chemists have been familiar for a long time; namely, that if a substance is capable of existence in two or more forms, it usually holds that the more unstable form appears instead of the stable form.

There is one exception to the statement that it is possible to carry one modification into the region of another and maintain it stable. None of the varieties of ice can be carried into the region in which liquid water is the stable form without the solid melting. It seems to be impossible to superheat a solid with respect to a liquid, although it is almost always possible to subcool a liquid with respect to a solid. This rule has been hitherto found to be of practically universal application at atmospheric pressure, and it is here seen to apply at high pressures also. Ice II behaves in a similar way with respect to ice III. Ice II may

not be superheated appreciably with respect to ice III, but III may be very considerable subcooled with respect to II. That is, III behaves with respect to II as if it were a liquid, although we know, by direct proof, that III is really a solid.

The manner in which one ice changes into another is truly remarkable. We know that water freezes slowly or that ice melts slowly, but some of these kinds of ice will change into another kind so rapidly that the reaction reminds one of an explosion. For instance, if ice I is changed to ice III at -25° , the reaction takes place so suddenly that it is impossible to follow the change of pressure which takes place after the reaction. On several occasions I have heard of a click in the apparatus when the transformation took place, so rapid was it. Still another remarkable thing is that the effect of temperature on the velocity of the reaction is very great indeed. If ice I is cooled to about -50° , the reaction occurs so slowly that it takes hours for its completion. Similar behavior is found also on the curves III-V and V-VI; the reaction from one solid form to another is very rapid indeed at temperatures near the melting temperature, but as the temperature is reduced the speed of the reaction becomes very much less. This is the reason that the curves separating the domains of the different kinds of ice could not be followed to lower temperatures than are shown in the diagram. At lower temperatures the reaction becomes so very slow that it would have taken days to obtain a single point. It is to be expected that the curves separating II and V and V from VI will continue to run to lower temperatures, that they will finally meet, and that from the point of intersection a new equilibrium curve, the curve between II and VI, will start. The point at which any three curves meet in the diagram is called a triple point. It will be noticed from the figure that two curves never meet without a third curve starting from the point of intersection of the other two. This is always true, provided that on two of the curves there is a phase in common; it may be proved mathematically that such is the case, but to prove this here would take us too far afield.

The fact that ice I gives place to ice II at a certain pressure has one practical application. We have often heard of the immense pressures developed when water is allowed to freeze in a closed vessel. Burst water pipes are a familiar example of

this, and there are also well-known experiments in which cannon balls have been split open by freezing water. It is of interest to inquire how much pressure might be reached in this way. The diagram furnishes an answer to the question, as it shows that if the pressure on the ice during freezing should rise to much over 2000 or 2×10^3 kgm., corresponding to 30,000 pounds per square inch, the ordinary ice would change to ice III, which has a much less volume, so that the ice would tend to shrink and the rise of pressure would be arrested. Thirty thousand pounds per square inch is, therefore, the highest pressure that can be obtained by freezing water in a closed space.

It may be of interest to give a rough idea of the difference of volume between the different forms of ice. To indicate the change of volume accurately, it is necessary to specify the pressure and the temperature at which the change from one variety to the other takes place, because the change of volume depends somewhat on both these factors. Roughly, ordinary ice,—ice I,—is from 10 to 13.5 per cent. less dense than water. Ice III is on the average 3 per cent. denser than water and 20 per cent. denser than ice I. Ice II is about 22 per cent. higher in density than ice I. Ice V is about 5.5 per cent. denser than ice III and perhaps 6 per cent. denser than water. Ice VI is 4 per cent. denser than ice V and from 9 to 5 per cent. denser than water.

The latent heat,—that is, the amount of the heat absorbed when ice melts to water,—is about the same for all the varieties denser than water that it is for the ordinary kind. The various modifications of the solid have, however, this remarkable relation to each other; namely, that the one may change to another in a large number of cases without any appreciable transfer of heat. Wherever, in the diagram, there is a transformation curve running vertically, then on that line the one solid form passes to the other without appreciable heat transfer. This fact allows the very sudden change from one solid form to another that has been commented on, because if there were any heat of transformation it would be set free during the reaction, and would have to be conducted away, which would take time. Therefore the reaction could not run faster than the heat could be conducted away. In those cases in which there is no heat to be conducted away the reaction might be very fast indeed. But the fact that there is no heat of transformation does not explain why the

reaction is very rapid; it simply makes a rapid reaction possible, provided that the other factors are favorable. This is shown by the fact that at the lower temperatures on the transformation curves there is still no heat of reaction, but the reaction, nevertheless, runs slowly.

A word as to the possibility of proving that the various new forms of ice that have been described are really solids. All that has been shown in the experiments is that at certain pressures and temperatures there is a sudden change of volume. This must mean a change of some kind in the molecular structure of the substance, but on what grounds can it be said that the change is a change to a solid form? May not there conceivably be two modifications of the liquid? The answer is, firstly, that no substance is known which has two modifications of the liquid, but that many are known which have two solid forms. None of our ideas of the molecular structure of solids or of liquids would lead us to think that two liquid forms of a substance are possible. Secondly, Tammann has given direct experimental proof that the two forms of ice, II and III, are really solid. He did this by cooling the cylinder containing the ice to the temperature of liquid air, and then opening the cylinder after pressure had been relieved, still keeping the temperature at that of liquid air. Of course, as soon as pressure was relieved, the ice II or III, whichever it happened to be, became unstable, but at this low temperature the reaction from the unstable to the stable, or ordinary ice, runs very slowly indeed, so that there was time enough to examine the contents of the cylinder, after opening it, before all the unstable variety had disappeared. It was found that the new substance was indeed a solid, and that as it changed into ordinary ice it increased greatly in volume. Tammann performed this experiment for both the varieties II and III. It might perhaps be possible to repeat the experiment for the other two varieties, V and VI, but the chances of success are very much less, because atmospheric pressure is so much further removed from the equilibrium pressure for these two varieties that the reaction would be expected to run very much more rapidly. What is more, the behavior of these new varieties is in all respects like that of the two varieties which we know to be solid; that is, under some conditions the reaction velocity is much greater than it ever is when a liquid passes to a solid. Also, in some cases

when one variety changes to another, enough pressure is exerted on the thin steel vessel containing the ice to rupture it. It is difficult to conceive how a liquid would develop enough pressure to rupture a steel vessel; one would expect instead that it would flow away, relieving the pressure as fast as it was formed. The overwhelming probability from all the evidence is, therefore, that the other two varieties, V and VI, are solid also.

Experiments which I have performed since these experiments on ice show that the ability to exist in more than one solid form is not confined, by any means, to water substance, but is in all probability a quite common property of matter at high pressures. I have found other modifications of six additional substances, several of them having more than two forms. One, ammonium nitrate, has five forms, the same in number as water. I am not aware that any substance has as yet been found with more than five solid forms. The equilibrium diagrams for these different substances do not bear any obvious relation to each other or to water; the diagram would seem to depend to very great degree on the individual properties of each substance.

Finally, as to a possible explanation of why a solid may have more than one form, there are two conceivable hypotheses: One is that the molecules are arranged differently in the different forms,—that is, in different space frameworks with different kinds of symmetry, so that the different solids belong to different crystalline systems. The other is that the molecules themselves are different in the different forms. For instance, it may be that when pressure and temperature have passed certain limits two or more molecules coalesce or associate and henceforth behave as one. Doubtless there will be found instances of both kinds of behavior; one might expect, however, that in the majority of cases the change in form is due to a rearrangement of the molecules, each molecule preserving its individuality. One reason for thinking that this will prove to be the case is that it is difficult to imagine how such exceedingly rapid change from one solid to another is possible if the molecules have to form new bonds with other molecules. The rapidity of reaction suggests rather that the molecules simply snap round on axes from one position of equilibrium to another. There is no way of being certain, however, what is the correct explanation in any special case, but this is a fertile subject for future investigation.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

REPORT OF THE DIRECTOR OF THE BUREAU.

THE annual report of the Director of the Bureau of Standards has recently appeared. An interesting development of the work of the Bureau is the growing demand for coöperation in connection with public-service commissions, and of the technical problems connected with the regulation of public utilities. The report says:

“The report of the activities of the Bureau during the year necessarily gives but the briefest summary of its work. In no year of its history has there been as full coöperation of all divisions of the Bureau in testing and research. This coöperation has minimized the somewhat narrowing effects of a rigid division system. Each problem when studied in a broad scientific spirit leads into every specialty, so that the fullest coöperation of the entire Bureau is essential to its success. The gratifying results of such coöperation are particularly notable in the development of standards for gas, in the researches upon metals, and the methods of testing the properties of materials, in the study of electrolysis experimentally and in the field, in the structural materials investigation, and in many other cases where success depends upon many specialties.

“In no case is such coöperation more striking than in the gradual development of the public-service commission work of the Bureau. This is an outgrowth of the weights and measures activity of the Bureau, of the coöperation with the Interstate Commerce Commission, and with other regulative and inspection services, notably the wireless service, the regulation of navigation, municipal gas regulation, standardization of specifications for materials, and central-station power service. The regulation of public utilities is distinctly a measured regulation of their technical details and is efficient only as it is based upon measures and standards. Public-utility regulation simply applies measurements and standards to new fields. Such regulation is effected by the specification of measurable standards for each element so

selected as to assure efficient service; these factors may be, for example, the measure of value, quality, size, composition, quality, speed, and the like. Safety even involves measures where, for example, safety depends upon the strength of the properties of materials or upon safe speed limits.

“Such work is an extension of the general purpose of the Bureau as a whole, coöperation in all movements which have for their object increase in efficiency in all fields through measurements and standards. The three hundred or more publications of the Bureau will give a fuller account of the researches and methods by which its work is accomplished.”

An interesting summary of the work of the Bureau in connection with the testing of cement is given in the report.

CEMENTS.

A total of 15,810 samples of cement were tested during the past fiscal year at the Washington, Pittsburgh, and Northampton laboratories, representing in Government purchases about 1,600,000 barrels. The work showed an increase of 15 per cent. at Washington, 40 per cent. at Pittsburgh and a decrease of 25 per cent. at Northampton due to a decrease in shipments to the Canal Zone.

Samples of cement to be used in construction of Federal buildings throughout the country and miscellaneous samples received from Government departments and the public were tested at the Washington laboratory; also cements to be used in the construction of docks and inland river improvements.

There were purchased on Government contracts 226,725 barrels of cement at 14 different mills located in Virginia, West Virginia, Maryland, Pennsylvania, New Jersey, New York, and Indiana, which were inspected at the place of manufacture. The inspection included the taking of samples, testing, and subsequent inspection of packing and shipping. This method of inspection is convenient to the purchasing office in that only standard cement is received, and it may be used immediately upon delivery; it is also economical, since fewer samples can be taken, fewer tests made, and shipments can be made immediately on any Government contract from tested stock.

At the Pittsburgh laboratory most of the routine testing was done for the War Department, complete inspection being made at

the place of manufacture. The cement for the Isthmian Canal was tested at Northampton. The decrease in shipments to the Canal Zone was caused by the completion of certain phases of the work.

Cement Specification.—In an endeavor to obtain a United States standard specification for Portland cement the Government conference of engineers from the various departments, which was successful in formulating a Government standard specification during the preceding year, was reconvened and a joint conference organized composed of representatives from the Government conference, the American Society of Civil Engineers, and the American Society for Testing Materials. While no final agreement has been reached by the joint conference, it is anticipated that a uniform specification may be agreed to during the ensuing year.

Investigations upon Cement and Concrete.—The experimental cement plant of the Bureau has been particularly active during the past year. In all 20 burns were made in the rotary kiln, part of these being of particular interest as bearing upon the effect of magnesia in Portland cement, which has been a much disputed question. The effect of difference of temperature of burns on the same raw material was also studied in the small "stack kiln," and very interesting results obtained. Before they can be considered conclusive they must be duplicated on a larger scale.

There has been conducted in the chemical and microscopical laboratory a great deal of work on the process of hydration of cements, particularly with the use of pure materials. A report of this work is now being prepared. The experimental cement plant has also devoted several weeks to work on clay, marl, and magnesite submitted by commercial interests.

Other investigations were continued or inaugurated during the year, such as a study of sand or silica cements, which is of considerable value to the Reclamation Service, which is now using this instead of Portland cement on some projects. The value of the soundness test and a proposed high-pressure steam test for determining the quality of the cement were investigated. Tests were also continued to determine the effects of heat, moisture, and pressure, separately and combined.

A granulometric analyzer and separator were developed in order to study the value of fine grinding of cements. An in-

vestigation was made to determine the sieving value of standard cement sieves. Work was continued on the investigation of volumetric changes which take place in concrete structures, owing to the temperature variations and chemical reaction during the hardening of the concrete; this information is necessary in order to properly place expansion and contraction joints to prevent cracking of concrete structures. This work has been done almost entirely in the field, experiments being made on roadways in Michigan, Connecticut, New Jersey, Pennsylvania, and Canada.

In order to determine the effect of alkali waters on cement as actually used in service an advisory committee was organized, composed of representatives from the Reclamation Service, the drainage division of the Department of Agriculture, the Cement Manufacturers' Association, and the Bureau. This committee held several meetings and organized a program of tests which included the making of some 8000 cement drain tile which are to be installed in eight badly alkaline districts in Colorado, Montana, Wyoming, Arizona, Washington, New Mexico, and Utah; also in Missouri and Minnesota for comparative purposes. These drainage tile are to be installed during the late summer of 1913.

An investigation was made to determine the failure of concrete in Bergen Hill Railway tunnel between Hoboken and Jersey City, N. J. This involves both laboratory and field tests which have not been completed.

Some work was done on the investigation of the permeability to water of structural materials, but it had to be temporarily discontinued.

A number of miscellaneous samples of stones, bricks, concrete, and building material were tested for various Government departments.

Steps were taken toward the organization of an advisory committee to outline a comprehensive coöperative program for a field survey and laboratory investigation of the stone resources of the United States. The committee is composed of representatives from the United States Geological Survey, the Bureau of Mines, the Office of Public Roads, and the Bureau of Standards. The work is to be done coöperatively by the various Government offices.

A publication was issued during the year (Technologic Paper No. 12) on the action of salts in alkali waters and sea water on cements.

COMPARISON OF THE SILVER AND IODINE VOLTAMETERS
AND THE DETERMINATION OF THE VALUE
OF THE FARADAY.*

By G. W. VINAL and S. J. BATES.

A FORM of iodine voltameter was devised by Washburn and Bates and described by them in the *J. Am. Chem. Soc.*, 34, p. 1341. This instrument was found to be of about the same order of reproducibility as the silver voltameter. Because of the reversibility of the reactions taking place at the anode and the cathode, and the character of the deposit which precluded the possibility of inclusions of foreign material, it seemed a desirable instrument to use in the determination of the faraday, especially since the values for this constant had heretofore been based on the silver measurements alone.

Accordingly arrangements were made for a comparison of the silver and iodine voltameters at the Bureau of Standards during the summer of 1913. The operation of the iodine voltameters was in general the same as previously described by Washburn and Bates. The silver voltameters were of the porous cup and Smith form following the usual procedure of the Bureau of Standards. Since the same current passed through the silver and iodine voltameters, the ratio of silver to iodine may be immediately calculated. As a result of ten experiments, in each of which several voltameters of both types were employed, we find the ratio

$$\frac{\text{Silver}}{\text{Iodine}} = 0.85017,$$

which is slightly higher than the ratio (0.84998) of the present atomic weights. All sources of error have been carefully examined and are critically discussed in the full paper. None, however, are believed to be sufficient to account for the difference between this value and the ratio of the present international atomic weights.

Using the results of the silver voltameter to measure the coulombs passing through the circuit according to the decision of the London Electrical Conference (1.11800 mg. of silver = 1 coulomb), the electrochemical equivalent of iodine is:

$$1.31502 \text{ mg. per coulomb.}$$

* To appear in full in the *Bulletin of the Bureau of Standards* and *Journal of American Chemical Society*. Communicated by E. B. Rosa.

The value of the faraday on the basis of the present international atomic weight of iodine (126.92) and the foregoing value of the electrochemical equivalent of iodine is:

$$\frac{126.92}{.00131502} = 96,515 \text{ coulombs.}$$

The value of the faraday derived from the atomic weight of silver and the defined electrochemical equivalent of silver is:

$$\frac{107.88}{.00111800} = 96,494.$$

The mean value of the two is 96,504, but we recommend for general use the round number 96,500.

THE SILVER VOLTAMETER.

PART IV.

FOLLOWING the work of the International Technical Committee at Washington in 1910, the Bureau of Standards has carried out an extended comparison of the porous cup and Smith forms of voltameter for the purpose of affording the added data necessary for the adoption of specifications for the voltameter. This work, which is about to be published by Messrs. Rosa, Vinal, and McDaniel, gives as the value for the Weston Normal Cell at 20° C. 1.01827 volts. This value justifies that adopted by the International Technical Committee (1.0183 volts). The two different forms of voltameters were found to be in good agreement, giving 1.01826₇ volts (porous cup form) and 1.01827₄ volts (Smith form).

The question of the effect of acid in the electrolyte was carefully examined. With pure electrolyte the acid causes a decrease in deposit for which a quantitative relation has been found. With impure electrolyte the results are very uncertain. Tests showed that the action of acid could not be attributed to a deposition of hydrogen ions at the beginning of the deposit, as had been suggested.

A study of the effect of septa other than filter-paper showed conclusively the danger of using silk to wrap the anode, as has sometimes been done. The porous pot, when properly prepared, is without action on AgNO₃.

The question of the purity of the deposit was studied, but the great experimental difficulties prevented an altogether satisfactory conclusion being reached. However, it is believed that in deposits made from very pure silver nitrate and presenting a perfect crystalline appearance the inclusions are very small.

The conditions under which the loss of weight at the anode is equal to the gain at the cathode were determined. Under favorable conditions the deposit of silver on the cathode and the loss of silver at the anode balanced to a high degree of accuracy. This would seem to disprove the existence of the secondary reactions believed by some previous observers to take place at the anode.

ELECTROLYSIS FROM ELECTRIC RAILWAY CURRENTS AND ITS PREVENTION.*

AN EXPERIMENTAL TEST ON A SYSTEM OF INSULATED RETURN FEEDERS IN ST. LOUIS.

THE paper describes a comparative test on electrolysis conditions, first under a system of uninsulated return feeders, and then under an insulated feeder system, installed at the Ann Avenue substation of the United Railways Company of St. Louis, Mo. The rated capacity of the Ann Avenue substation is 4000 kilowatts, and at the time of the test the average current during the hour of maximum load was about 7500 ampères. Only one single track passed immediately in front of the station, and one other single track passed along a street a block distant. The location was thus unfavorable to the return of current to the station, and a relatively large amount of negative copper would be required under any system.

The negative feeders were so installed that they could be operated either as insulated or uninsulated feeders, and tests were made to show the relative effectiveness and cost of the two systems.

The total weight of copper originally installed by the United Railways Company as uninsulated negative feeders was 65,630 pounds. When the system was converted to an insulated negative feeder system the weight of copper was increased to 80,720

* Abstract of Technologic Paper No. 32.

pounds to reduce the potential gradient in the rails return at all points of the system to a satisfactory value.

The bonding of the track was carefully examined and bad bonds were replaced. Tests were then made with the feeders insulated and uninsulated, the same amount of copper being used in each test.

Rail gradients were taken on a measured length of four feet of rail on all rails on both sides of each feeder tap.

The average rail gradient with uninsulated feeders was 0.91 volt for the 24-hour period, while the corresponding value for the insulated feeders was 0.47 volt.

With the assistance of the city water department and the gas company, potential wires were placed four feet apart on 14 water and 7 gas pipes at points where the current on the pipes would probably be the largest.

Readings of the millivolt drop on the pipes, and data on the size and kind of pipe, permitted the computation of the currents carried on these pipes. These measurements showed that the average current flow on the pipes when the uninsulated feeder system was in operation was 5.7 times greater than under the insulated feeder system, there being no metallic connection between pipes and rails in either case.

Potential differences between water pipes and rails were observed at a large number of points and show a marked improvement under the insulated system. The results are given under three groups. All of the points at which the pipe were more than 1 volt positive to rails under the uninsulated system average 2.35 volts under that system, and 0.22 volt with uninsulated feeders, showing a reduction in the ratio of over 10 to 1. On the other hand, eight points which averaged 0.39 volt negative to rails with uninsulated feeders showed an average value of 0.35 volt positive to rails with insulated feeders. The positive area with insulated feeders is shown to be increased, but the potential differences are nowhere high enough to be dangerous.

Twenty-two over-all potentials were measured between the tracks at the substation and the most distant feeding points of the substation. The average of those values was 10.4 volts with uninsulated and 2.6 volts with insulated feeders. The corresponding gradients in volts per thousand feet were 2.6 volts and 0.35 volt respectively.

Data are also given on the cost of the two systems, and show comparatively little difference in net cost, while a summary of the test data shows that electrolysis conditions are very much better under the insulated return feeder system than under the uninsulated system.

THE PRODUCTION OF TEMPERATURE UNIFORMITY IN AN ELECTRIC FURNACE.*

By ARTHUR W. GRAY.

AFTER discussing some fundamental principles underlying temperature control, and reviewing previous attempts to secure temperature uniformity in electric furnaces, the author shows how heat losses from the ends of a long air column may be materially lessened by means of a plug formed of two thick blocks of a good heat conductor. He then describes the development of an electric furnace in which the longitudinal temperature gradient was controlled by the use of such plugs combined with end-heating coils. Numerous illustrations make clear the construction of the furnace and accessories, and contrast the temperature distributions obtained with those obtained by other experimenters in this field.

The method has made it possible to heat a region of considerable length to any desired temperature up to 700° C. so uniformly that irregularities in the temperature distribution will be less than the effect of heterogeneity in thermo-elements of the best quality, and probably less than the uncertainties at present existing in our knowledge of the temperature scale itself.

INDUSTRIAL GAS CALORIMETRY.†

By C. W. WAIDNER and E. F. MUELLER.

AFTER an outline of the object of the investigation, precise definitions of the heat units and of the several heats of combustion are considered. After reference to the more important types of calorimeters that have been applied to the measurement

* Abstract of a paper soon to appear in the *Bulletin of the Bureau of Standards*.

† Technologic Paper of the Bureau of Standards.

of the heating values of gases, the principle of the flow calorimeter is set forth, and an example is given showing the reductions of and corrections to the observed data that are required in order to find the total and net heating values.

The results of an experimental investigation of laboratory gas meters, showing the errors to which such meters are liable, the precautions to be observed, and the accuracy attainable in their use, are given at length. It is shown that an accuracy of about 0.2 per cent. may be attained if the meter is calibrated *in situ* at the time of use, and that the calibration may be reproduced from time to time, by making suitable adjustments, to an accuracy of about 0.5 per cent.

The results are given of an extended series of investigations of the various factors that may affect the accuracy of heating value determinations with flow calorimeters, such as: completeness of combustion; accuracy of the temperature measurements; the magnitudes of the various heat losses from the calorimeter, particularly as affected by the volume of the entering air and of the products of combustion and by the atmospheric humidity; and the accuracy of measurements of the quantities of water and of gas. The effects of certain other factors, which depend on the nature of the gas tested and are particularly noticeable in the testing of illuminating gas, are briefly considered.

The results are given of an extended series of experiments with natural gas and with nearly pure hydrogen which show that, when the necessary corrections for losses of heat from the surface, for the effect of atmospheric humidity, etc., were applied to the observed heating values obtained with flow calorimeters of suitable design and construction, the total heating values thus found were in agreement to about 0.3 per cent. with the total heating value obtained with calorimeters of the Berthelot bomb type, provided due allowance were made for the difference between the heat of combustion at constant pressure and the heat of combustion at constant volume. The results obtained with illuminating gas indicated that the heating values obtained with the Berthelot bomb type of calorimeter were probably in error, being too low (about 1 per cent.), but further investigation will be required to determine the cause of the discrepancy found.

The summarized results are given of a critical investigation of eight flow calorimeters, representing types widely used in

this country or abroad, and of one calorimeter of the comparison type.

The investigation has shown that several of the calorimeters that were investigated could be used, when proper precautions were observed and suitable corrections were applied to the observed heating values obtained with them, to determine the total heating values of most kinds of gases to an accuracy of about 0.3 per cent. Some of the calorimeters are, however, subject to constant errors that cannot be eliminated or be readily determined except by comparison with a standard instrument, such errors for one calorimeter amounting to nearly 2 per cent.

Examination of a very large amount of data obtained during the investigation indicates that with those calorimeters free from significant constant errors total heating values should be determinable, under conditions obtaining in the practical testing of gas, to an accuracy of the order of 1 per cent.

STANDARD DENSITY AND VOLUMETRIC TABLES.*

A NEW and somewhat enlarged edition of Circular No. 19, of the Bureau of Standards, is soon to appear. An idea of the scope of the tables included in this circular may be gained from the outline which follows:

Table 1 gives the density of water (according to P. Chappuis) at every tenth of a degree from 0° to 40° C.

Tables 2 to 8, inclusive, are standard density and specific gravity tables for ethyl alcohol. They are based on work done at this Bureau and published in Vol. 9, No. 3, of the Bulletin of the Bureau of Standards (Reprint No. 197).

Tables 9 to 11 are similar tables for methyl alcohol. They are based on the work of Doroshevskii and Rozhdestvenskii.

Tables 12 and 13 are density tables for sugar solutions.

Tables 14 and 15 are density tables for sulphuric acid solutions.

Tables 16 to 19 give the relation between specific gravity and degrees Baumé in use in the United States.

Table 20 is for changing the density basis of hydrometers and picnometers.

* Circular No. 19, 4th edition.

Table 21 gives the weight of a litre of air at various pressures and temperatures.

Table 22 gives the difference between the weight of 1 c.c. of water *in vacuo* and in air at various pressures and temperatures.

Table 23 gives the apparent weight of various volumes of water at various temperatures when weighed against brass weights in air.

Table 24 gives the temperature correction for glass volumetric apparatus.

Tables 25 to 37 give the corrections to be applied to the weight of water, in air, to give the capacity of glass volumetric apparatus.

Table 38 gives the density of water (according to Thiesen) at temperatures from 0° to 102° C.

Tables 39 and 40 are master scales for the graduation of hydrometers to indicate percentages of ethyl alcohol by weight and by volume and percentages of "proof spirit."

König's New Process for the Manufacture of Cellulose. A. FROHBURG. (*Wochenbl. Papierfab.*, xliv, 4432.)—In König's process, owing to the action of the sulphuric acid, the production of sugar would amount to 10 to 17 per cent. of the wood, or even more, whereas in the sulphite process it is never more than 7 per cent. Consequently the yield of cellulose by the new process would be lower and in quality it would be of the nature of a hydrocellulose. The consumption of steam in the digestion would be four times as great as in the digestion by the sulphite process. The total time occupied in the digestion and the cycle of attendant operations would be 27 hours, as against 14 to 20 hours by the sulphite process. Taking the cost of materials and steam per ton of unbleached cellulose, König's process would require an expenditure of about \$60, including costs of evaporation and recovery, from which must be deducted \$18.50 for the value of useful by-products (resin, tannin, and fodder-material) recovered, while the similar costs of the sulphite process, without recovery, would amount to about \$27.50 per ton.

Fertilizers Containing Acid Phosphate and Calcium Cyanamide. R. N. BRACKETT. (*J. Ind. Eng. Chem.*, v, 933.)—Laboratory experiments and experience on a factory scale both show that in mixed fertilizers containing one part of calcium cyanamide to 6.25 or 8.33 parts of acid phosphate (super-phosphate), with or without "ammoniates" and potash salts, there is a gradual increase of the insoluble and decrease of the available phosphoric acid on standing.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, February 18, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 18, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 10.

The standing committees of the year 1914-15 were announced.

Following the meeting of the Institute for the transaction of this business, a joint meeting was held with the Illuminating Engineering Society.

Dr. George A. Hoadley, chairman of the Philadelphia Section of the Society, introduced Dr. Herbert E. Ives, of Philadelphia, who presented an interesting communication on "Artificial Daylight."

The speaker discussed the problem of producing artificial light of daylight color and quality.

Various systems of color measurement were described as applied to daylight and artificial light.

Artificial daylight was produced by several methods, and its use in the industries considered at length.

An artificial daylight producer was exhibited which can be used with the Welsbach light, or, with a slight modification, with the tungsten electric lamp. A new glass was also shown for the first time, which makes possible the converting of the light of the gas mantle into true daylight.

Lantern slides were used to further illustrate the subject.

In the discussion which followed the presentation of the paper, Messrs. Bond, Henderson, Calvert, Hornor, and others participated.

After a vote of thanks to the speakers, the meeting adjourned.

R. B. OWENS,

Secretary.

STANDING COMMITTEES, 1914.

Of the Board of Managers.

INSTRUCTION.

Lawrence T. Paul, *Chairman*,
Edw. V. McCaffrey,
George A. Hoadley,
James S. Rogers,
Harry F. Keller.

ELECTIONS AND RESIGNATIONS.

W. C. L. Eglin, *Chairman*,
J. J. Gibson,
Robert Perry,
Alex. P. Robinson,
George D. Rosengarten.

STOCKS AND FINANCE.

Walton Forstall, *Chairman*,
Cyrus Borgner,
Alfred C. Harrison,
Richard Waln Meirs,
E. H. Sanborn.

PUBLICATIONS.

Louis E. Levy, *Chairman*,
John Birkinbine,
W. C. L. Eglin,
George A. Hoadley,
E. H. Sanborn.

EXHIBITIONS.

John Birkinbine, *Chairman*,
Francis T. Chambers,
E. Goldsmith,
C. A. Hexamer,
Marshall S. Morgan.

SECTIONAL ARRANGEMENTS.

Charles Day, *Chairman*,
Harry F. Keller,
Robert W. Lesley,
Louis Levy,
Lawrence T. Paul.

ENDOWMENT.

Henry Howson, *Chairman*,
James M. Dodge,
Alfred C. Harrison,
Richard Waln Meirs,
Coleman Sellers, Jr.

EXECUTIVE.

E. H. Sanborn, *Chairman*,
James M. Dodge,
Walton Forstall,
Alfred C. Harrison,
Richard Waln Meirs.

Of the Institute.

COMMITTEE ON LIBRARY.

Robert H. Bradbury,
E. V. d'Invilliers,
Richard Gilpin,
Clarence A. Hall,
Harry F. Keller,
Gaetano Lanza,
Henry Leffmann,
Louis E. Levy,
Marshall S. Morgan,
George F. Stradling.

COMMITTEE ON MEETINGS.

G. S. Barrows,
G. H. Clamer,
Geo. R. Henderson,
H. A. Hornor,
Herbert E. Ives,
M. M. Price,
James S. Rogers,
Geo. D. Rosengarten,
Coleman Sellers, Jr.

COMMITTEE ON MUSEUMS.

Henry F. Colvin,
Charles Day,
James M. Dodge,
Richard Gilpin,
George A. Hoadley,

Harry F. Keller,
Wilfred Lewis,
A. E. Outerbridge, Jr.,
Wm. H. Thorne,
Wm. J. Williams.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday,
February 4, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 4, 1914.

DR. GEO. A. HOADLEY, *Chairman pro tem.*

Mr. George R. Henderson was unanimously elected Chairman for the year 1914.

The following reports were presented for final action:

No. 2524.—Sperry's Gyro-Compass. John Scott Legacy Medal and Premium recommendation adopted.

No. 2530.—Stumpf's Una-Flow Engine. Referred back.

No. 2534.—Reno's Escalator. John Scott Legacy Medal and Premium recommendation adopted.

No. 2542.—Batdorf's Coin Counting and Wrapping Machine. John Scott Legacy Medal and Premium recommendation adopted.

No. 2587.—Spielman's Cloth Cutting Machine. John Scott Legacy Medal and Premium recommendation adopted.

The following report was presented for first reading:

No. 2541.—Guillaume's Invar.

Adjourned.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the section was held in the Hall of the Institute on Thursday, January 29, 1914, at 8 P.M., with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were read and approved.

W. P. Mason, C.E., M.D., LL.D., Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y., delivered a lecture entitled "Advantages and Disadvantages of Water Storage." It was demonstrated that still water rather than running water offers the better conditions for self-purification. Examples of lake pollution of unusual type were given, and the methods of study of the influence of possible sources of pollution on water supply were described. The removal of algæ from water by means of cupric sulphate was also discussed. The lecture was illustrated by means of lantern slides.

After an extended discussion of the various phases of water storage, contamination, and purification, the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.**Elections to Membership.**

(Stated Meeting, Board of Managers, February 11, 1914.)

RESIDENT.

- MR. SAMUEL J. CASTNER, 1631 Walnut Street, Philadelphia.
MR. SABIN W. COLTON, JR., 328 Chestnut Street, Philadelphia.
MR. CHARLES GOBRECHT-DARRACH, 5825 Willows Avenue, Philadelphia.
MR. W. H. LLEWELLYN, 1518 Chestnut Street, Philadelphia.
MR. AUSTIN G. MAURY, Northeast corner Chestnut and Third Streets, Philadelphia.
MR. HORACE B. SMITH, 3206 Higbee Street, Wissinoming, Pa.

NON-RESIDENT.

- MR. A. C. HOWARD, United Gas and Electric Engineering Corporation, 37-39 Pine Street, New York.
MR. FRANK W. SMITH, Vice-President, The United Electric Light and Power Company, 1170 Broadway, New York.

ASSOCIATE MEMBERS.

- MR. PENROSE R. HOOPES, Autocar Works, Ardmore, Pa.
MR. MARSHALL MILLER, Powers, Weightman & Rosengarten, Ninth and Parrish Streets, Philadelphia.

Changes of Address.

- PROF. J. D. BALTIMORE, 505 U Street, N. W., Washington, D. C.
MR. JOHN CALDER, International Motor Company, Detroit, Mich.
MR. FRED A. DELANO, 1414 Transportation Building, Chicago, Ill.
MR. L. J. R. HOLST, Hotel Hampton, 112 North Eighteenth Street, Philadelphia.
MR. A. S. KREBS, 806 Franklin Street, Wilmington, Del.
MR. PEDER LOBBEN, Skobdo, Pr. Kraakstad, Norway.
MR. JOHN W. TOWNSEND, 825 Montgomery Avenue, Bryn Mawr, Pa.
MR. J. S. WHITNEY, 33 South Sixteenth Street, Philadelphia.

NECROLOGY.

William D. Marks, consulting mechanical engineer, honorary life member of the Institute, was born in St. Louis in 1849. He was educated at Yale University, and was graduated as Bachelor of Philosophy in 1870, and Civil Engineer in the following year. Until 1876 he was engaged in practical engineering work in connection with railway and gas and iron works, when he became instructor in mechanical engineering at Lehigh University. In 1876 he was appointed Whitney Professor of Dynamical Engineering at the University of Pennsylvania. He was superintendent of the 1884 International Electrical Exhibition of The Franklin Institute, to the great success of which he greatly contributed. In 1887 he was appointed engineer and president of

the Edison Electric Light Company of Philadelphia. His later years were devoted to consulting work.

Professor Marks was a member of the American Institute of Electrical Engineers and a member of the American Philosophical Society. He was the author of a number of books and papers on mechanical and engineering subjects, and a frequent contributor to the JOURNAL OF THE FRANKLIN INSTITUTE.

Mr. Elijah R. Benham, 6 Central Avenue, New London, Conn.

Mr. Otto Moessner, Twenty-first Street and Fairmount Avenue, Philadelphia, Pa.

LIBRARY NOTES.

Purchases.

American Society for Testing Materials.—Proceedings 16th Annual Meeting. 1913.

CAMPBELL, N. R.—Modern Electrical Theory. 1913.

CUSHING, H. C., and SMITH, F. W.—Electric Vehicle Handbook. No date.

DYSON, C. W.—Screw Propellers. 2 volumes. Vol. 1, Text. Vol. 2, Atlas. 1913.

FULLER, H. C.—Qualitative Analysis of Medicinal Preparations. 1912.

GILDEMEISTER, E., and HOFFMAN, F.—The Volatile Oils. 1913.

GULLIVER, G. H.—Metallic Alloys. 1913.

HYDE, F. S.—Solvents, Oils, Gums, Waxes. 1913.

LANGBEIN, G.—Complete Treatise on the Electro-Deposition of Metals. 1913.

MACINTIRE, H. J.—Mechanical Refrigeration. 1914.

MARKHAM, E. R.—Steel, its Selection, Annealing, Hardening, and Tempering. 1913.

MAUBORGNE, J. O.—Practical Uses of the Wave Meter in Wireless Telegraphy. 1913.

New Hampshire Public Service Commission.—2nd Annual Report. 1912.

PALMER, R. H.—Foundry Practice. 1912.

PARKER, P. A. M.—Control of Water. 1913.

PORRITT, B. D.—Chemistry of Rubber. 1913.

PUTNAM, X. W.—Gasoline Engine on the Farm. 1913.

RICHARDS, F.—Compressed Air Practice. 1913.

RIPPER, W.—Heat Engines (being a new edition of "Steam"). 1913.

ROBERTS, C., and SMITH, R. M.—Practical Locomotive Operating. 1913.

SCHULTZ, G. and J. P.—Farbstofftabellen. 1911-13.

TILLMANS, J.—Water Purification and Sewage Disposal. 1913.

ZEEMAN, P.—Researches in Magneto-optics. 1913.

Gifts.

American Railway Master Mechanics' Association, Proceedings, vol. 46, 1913. Chicago, 1913. (From the Association.)

American Society of Heating and Ventilating Engineers, Transactions, vol. 18, 1912. New York, 1913. (From the Society.)

- Boston Transit Commission, 19th Annual Report, 1913. Boston, 1913. (From the Commission.)
- Boullanger, Experiences et Observations Sur le Spath-vitreux, on Fluor Spathique. 1773. (From Dr. Henry Leffmann.)
- Carnegie Institution of Washington, Year Book No. 12, 1913. Washington, D. C., 1913. (From the Institution.)
- Case School of Applied Science, Catalogue 1913-1914. Cleveland, 1913. (From the School.)
- Columbia University in the City of New York: Publication No. 7 of the Ernest Kempton Adams Fund for Physical Research, Neuere Probleme der Theoretischen Physik, by W. Wien. Leipzig, 1913. (From the University.)
- Connecticut Bureau of Vital Statistics, 65th Registration Report. Hartford, 1913. (From the Bureau.)
- Engineering Society of Shanghai, Proceedings, vol. 12. Shanghai, China, 1913. (From the Society.)
- Iron and Steel Institute, Journal, vol. 88, 1913, part 2, and List of Members, 1914. London, 1913 and 1914. (From the Institute.)
- Joseph Dixon Crucible Company, Graphite, 1913. Jersey City, 1913. (From the Company.)
- Lake Superior Mining Institute, Proceedings, vol. 18, 1913. Ishpeming, 1913. (From the Institute.)
- Leland Stanford Junior University, Annual Report of the President, 1913. Stanford University, Cal., 1913. (From the University.)
- Maine State Department of Labor and Industry, 1st Biennial Report, 1911-1912. Augusta, 1913. (From the Department.)
- Master Builders of the World's Greatest Structure. New York, 1913. (From Mr. Richard Gilpin.)
- Master Car Builders' Association, Proceedings, vol. 47, 1913, parts 1 and 2. New York, 1913. (From the Association.)
- Mellon Institute of Industrial Research, University of Pittsburgh: Smoke Investigation Bulletin No. 5, The Meteorological Aspect of the Smoke Problem, by H. H. Kimball. Pittsburgh, 1913. (From the University.)
- Mount Holyoke College, Catalogue 1913-1914. South Hadley, Mass., 1914. (From the College.)
- New Jersey Geological Survey, Bulletins 2-4, 6-11. Trenton, 1911-1913. (From the Survey.)
- New York State Education Department, State Museum Report, 65th, 1911, vols. 1-4. Albany, 1913. (From the State Library.)
- Pennsylvania Life, Fire and Marine Insurance Report, 1912. Harrisburg, 1913. (From the State Librarian.)
- Pennsylvania Lines West of Pittsburgh, A History of the Flood of March, 1913. Pittsburgh, 1913. (From the Pennsylvania Railroad Company.)
- Pennsylvania Topographic and Geologic Survey: Report for 1910-1912 and Report No. 6, Commission Graphite Deposits of Pennsylvania, by B. L. Miller. Harrisburg, 1912. (From Dr. E. V. d'Inwilliers.)
- Philadelphia Bureau of Surveys, Annual Report, 1912. Philadelphia, 1913. (From the Bureau.)

- Philadelphia Steam Heating Company, Catalogue. Philadelphia, 1914. (From the Company.)
- Philippine Islands Bureau of Education, 13th Annual Report of the Director. Manila, 1913. (From the Bureau.)
- Princeton University, Catalogue 1913-1914. Princeton, 1913. (From the University.)
- Royal Astronomical Society of Canada, The Observer's Handbook for 1914. Toronto, 1914. (From the Society.)
- St. Andrew's Society of Philadelphia, Historical Catalogue, vol. 2, 1749-1913, compiled by Robert B. Beath. Philadelphia, 1913. (From the Compiler.)
- St. Louis and San Francisco Railroad Company, 16th Annual Report, 1912. St. Louis, 1912. (From the Company.)
- Shepard Iron Works, Catalogue of Perry & Lay Compound Engine. Buffalo, no date. (From Mr. John T. Morris.)
- United States Brewers' Association, Year Book 1913. New York, 1914. (From the Association.)
- United States Coast and Geodetic Survey: Special Publication No. 17, Triangulation on the Coast of Texas, from Sabine Pass to Corpus Christi Bay. Annual Report of the Superintendent, 1913. Washington, D. C., 1913. (From the Survey.)
- University of Cincinnati, Annual Catalogue, 1913-1914. Cincinnati, 1914. (From the University.)
- University of Illinois, Reports of the Registrar and Comptroller, June 30, 1913. Urbana, 1913. (From the University.)
- University of Oklahoma, General Catalogue 1912-1913. Norman, 1913. (From the University.)
- University of Virginia, Catalogue 1913-1914. Charlottesville, 1914. (From the University.)
- Victoria and Albert Museum, South Kensington, Catalogue of the Mechanical Engineering Collection in the Science Division, parts 1 and 2. London, 1907 and 1908. (From Mr. Edward H. Sanborn.)
- Wellesley College, Calendar 1913-1914. Wellesley, Mass., 1914. (From the College.)

BOOK NOTICES.

A TREATISE ON QUANTITATIVE INORGANIC ANALYSIS, with Special Reference to the Analysis of Clays, Silicates and Related Minerals—being Volume One of a Treatise on Ceramic Industries. By J. W. Mellor, D.Sc. 778 pages, illustrations, plates, 8vo. London, Charles Griffin & Co., Ltd.; Philadelphia, J. B. Lippincott Company, 1913.

This work is accurately described by its title. It becomes at once a standard work in this special line of ceramic chemistry, as it seems to fully cover the field. The amount of text, considerable as it is found to be, is not a measure of the vast amount of material collected, as there are footnotes on nearly every page that seem to be satisfactory in their completeness.

Pages 1 to 151 are devoted to general operations under 77 headings,

and go very fully into gravimetric and volumetric processes, volumetric analysis, colorimetry, filtration and washing, heating and drying, sampling and reagents.

The body of the book is devoted to the chemical analysis of all the constituents of clays and materials, such as enamels and glazes. Of course, this very nearly covers the field of inorganic chemistry, and special methods for the estimation of elements, such as molybdenum, tungsten, niobium, tantalum, selenium, beryllium, vanadium, and uranium are given.

The third section of the work is the appendix, which is headed by a quotation from J. C. Maxwell, "The human mind is seldom satisfied, and is certainly never exercising its highest functions when it is doing the work of a calculating machine." The author has endeavored to keep the reader from doing any detail work of this kind, by doing it all himself, as he has given a number of conversion tables for calculating weights of precipitates to substances sought. It is probable, however, that every analyst has a slightly different system, and Dr. Mellor's would not fit in all cases.

There is a carefully-selected bibliography, and good name and subject indices are supplied. Very many of these methods would apply to other lines of analytical work than those which belong to the ceramic industries.

S. S. SADTLER.

THE GYROSCOPE. By F. J. B. Cordeiro, author of "The Atmosphere," "Barometrical Heights," etc. 105 pages, illustrations, 12mo. New York, Spon & Chamberlain, 1913. Price, in cloth binding, \$1.50.

Within the last two or three decades the gyroscope has found various practical applications, and this has naturally stimulated interest in the study of the perplexing freaks of this instrument. This interest is met by the monograph "Gyroscope," by F. J. B. Cordeiro.

In this treatise gyroscopic reactions are treated as essentially of the nature of centrifugal force. This is true in so far as both the gyroscopic force and centrifugal force are reactions attending a change of the direction of moving bodies.

The subject is treated both in its mathematical and practical aspects, and its applications to astronomy and meteorology, as well as to the mechanic arts, are fully discussed.

HUGO BILGRAM.

NOTIONS FONDAMENTALES DE CHIMIE ORGANIQUE, par Charles Moureu, Professeur à l'École supérieure de Pharmacie de l'Université de Paris. Gauthier-Villars, Paris. 383 pages, 23 x 14 cm. Price, 9 francs.

Something like two hundred thousand compounds of carbon are known at present, and the problem of selecting the indispensable things for the beginner, out of the vast accumulation, is one of increasing difficulty. The present book is an excellent elementary account of the subject of organic chemistry. It possesses, in a high degree, that clearness and precision of statement which is such an excellent characteristic of French scientific writing. It differs, however, from many French books, in the fact that Professor Moureu is entirely familiar with the recent developments in his subject. There is an excellent account of Fischer's work on the sugars, and his researches on the

purin nucleus and on the polypeptides are briefly but clearly sketched. Important recent work, like the synthesis of caoutchouc, Grignard's organo-magnesium compounds, Harries's ozonides of the olefines, and the diazo-methane derivatives, receives brief but clear and adequate treatment.

The book is beautifully printed. The reviewer notes, with especial pleasure, the use of a matte-finish paper which suppresses the reflections that commonly dazzle and annoy. This is a French custom that might, with great advantage, be imitated by publishers of other nationalities. There is a good index. An English translation of this book would fill a gap in our own literature. There is no small work on the subject which covers the ground in such a thoroughly satisfactory way.

ROBERT H. BRADBURY.

THE MECHANICAL ENGINEER'S REFERENCE BOOK. A Hand-book of Tables, Formulas, and Methods for Engineers, Students, and Draftsmen, by Henry Harrison Suplee, B.Sc., M.E. 4th edition, revised and enlarged. 964 pages, illustrations, 12mo. Philadelphia, J. B. Lippincott Company, 1913. Price, \$5.

The fourth edition of this book is a beautiful specimen of the work of the typographer and bookbinder. The type, tables, and sketches are very attractive and easily read, and the thumb index for turning instantly to the various sections will commend itself to those who wish to find the general subjects without searching the index for some individual title.

While this book naturally bears many of the ear-marks of an engineer's hand-book, yet it has a distinct individuality of its own in many ways. It is rather unusual, for instance, to find in the trigonometrical tables values of the versed sine and cosine. These are very useful and save the time of making subtractions. The general trigonometrical and integral formulas are very clearly printed and in very convenient form; the same may be said of the formulas for acceleration and retarded motion, as these are so tabulated that they can be readily selected to suit the desired case. The tables are given in both the English and metric units, which is a distinct advantage, now that metric measurements are being so much used. The formulas for rotary motion and those of work in moving and revolving bodies are given with a great variety of constants so that the proper form can be selected without reductions.

We are rather surprised, however, to find the old laws of friction as exposed by Morin are still adhered to; whereas we know, and particularly from the M. C. B. brake tests, that the coefficient of friction does depend very largely upon the areas in contact. It would seem that these should have been rewritten in the light of modern experiments.

The sketches showing pipe fittings, valves, etc., are very convenient for designing pipe work. When it comes to the tables of structural sections, we are rather surprised to see the Pencoyd shapes alone illustrated and no reference made to the Carnegie sections, which are much more generally used by engineers than the Pencoyd; neither do we find any reference to the Bethlehem special beam and H sections. The spring formulas also do not show the general method of making springs, but seem to have been taken bodily from Reuleaux without being modernized to suit present practice.

The strength of gears is shown only for cast iron and steel, whereas many forms of metal are used, and it seems as if the coefficients given would be too high for good practice, such as in cranes and other important gearing. The efficiency diagram, however, is very interesting and useful.

In connection with the heat given out by iron pipes as in steam heating, there are values given for still air and moving air, but the latter must be considered as moving with a very low velocity, as the values are only about 30 per cent. greater than with still air, and it is well known that when the air is forced over the pipes by means of a fan we get values four to six times as great as with still air, and this is liable to be misunderstood from the tables given.

The tables of hyperbolic logarithms are for quite a large range and in very convenient type; but the locomotive data are limited to about a page and a half, and no formulas are given for tractive power of other than simple locomotives. It seems as if this locomotive data could have been extended and enlarged with advantage to this subject.

The record of electric motor tests will be found very interesting and useful in determining the amount of power needed for machine shops and similar propositions, and the chapter on the cost of power, giving the results of various kinds of fuel and electric drives, is particularly useful for comparison. The insertion of entropy tables in a work of this kind is rather unusual, and several pages are given to an explanation of the entropy-temperature diagram.

The book as a whole will be extremely useful to engineers, and seems to cover a very wide range of subjects, more so, perhaps, than any of the other hand-books which we have in mind at the present time.

GEORGE R. HENDERSON.

LES CLASSIQUES DE LA SCIENCE. Publiés sous la direction de MM. H. Abraham, H. Gautier, H. Le Chatelier, J. Lemoine. Paris, Librairie Armand Colin, 1913.

No. 1. L'Air, L'Acide Carbonique et L'Eau. Mémoires de Dumas, Stas, et Boussingault. Avec 4 planches hors texte.

No. 2. Mesure de la Vitesse de la Lumière, Étude Optique des Surfaces. Mémoires de Léon Foucault. Avec 3 planches hors texte.

No. 3. Eau Oxygenée et Ozone. Mémoires de Thénard, Schoenbein, De Marignac, Soret, Troost, Hautefeuille et Chappuis.

No. 4. Molécules Atomes et Notations Chimiques. Mémoires de Gay-Lussac, Avogadro, Ampère, Dumas, Gaudin, Gerhardt. Avec 1 planche hors texte.

The idea of publishing at popular prices this new series of the classics of physics and chemistry was evidently suggested by publications in other languages, particularly the comprehensive and most successful collection which Ostwald began in 1889 under the similar title "Klassiker der Exakten Wissenschaften."

As has been frequently said, the most profitable and stimulating collateral reading for scientific students is that of the original memoirs by the great investigators and discoverers. Any teacher who has succeeded in interesting his pupils in this kind of literature could not fail to notice its effect in broad-

ening and promoting their scientific understanding. The present collection is, of course, primarily intended for the French-speaking student, and for this reason it is but natural that it consists for the most part of reprints of memoirs which were originally written in French. In this respect it differs from the Ostwald series, and it also has a more pronounced national flavor than, for example, the excellent "Alembic Club Reprints" of chemical classics. But this is hardly a defect from the foreign reader's point of view; for the collection thus affords an admirable supplement to the corresponding publications in other languages. In addition to the excellently selected memoirs, each little volume contains short biographical notices of their authors, as well as fine fac-simile reproductions of the illustrations. Considering the very moderate price at which these little books are offered, their appearance is most attractive. Type, paper, and illustrations are decidedly better than those of the similar German and English publications.

H. F. KELLER.

PUBLICATIONS RECEIVED.

Die Entdeckung des Radiums, Rede gehalten am 11 Dezember, 1911, in Stockholm, bei Empfang des Nobelpreises für Chemie von Mme. P. Curie. Autorisierte Deutsche Ausgabe mit 5 Abbildungen. 28 pages, 8vo. Leipzig, Akademische Verlagsgesellschaft m. C. H., 1912.

Letzte Gedanken von Henri Poincaré, mit einem Geleitwort von Wilhelm Ostwald. Übersetzt von Dr. Karl Lichtenecker. 261 pages, portrait, 12mo. Leipzig, Akademische Verlagsgesellschaft m. b. H., 1913.

Der Werdegang einer Wissenschaft Sieben gemeinverständliche Vorträge aus der Geschichte der Chemie von Wilhelm Ostwald. 2 vermehrte und verbesserte Auflage der "Leitlinien der Chemie." 316 pages, 12mo. Leipzig, Akademische Verlagsgesellschaft m. b. H., 1908.

Die elektrolytische Alkalichloridzerlegung mit festen Kathodenmetallen herausgegeben von Dr. Jean Billiter, Privatdozent an der Universität Wien. II Teil Beschreibung ausgeführter Anlagen usw. 182 pages, illustrations, 8vo. Halle (Saale), Wilhelm Knapp, 1913. Price, in paper, 9.60 marks.

Cours de Mécanique professé à l'École Polytechnique par Leon Lecornu, membre de l'Institut, Inspecteur Général des Mines. Tome I. 536 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1914. Price, in paper, 18 francs.

Industrial Chemistry for Engineering Students, by Henry K. Benson, Ph.D., Professor of Industrial Chemistry in the University of Washington. New York, The Macmillan Company, 1913.

Das Werden der Welten von Svante Arrhenius. Aus dem Schwedischen übersetzt von L. Bamberger. 9 bis 13 Tausend mit 60 Abbildungen im Text. 231 pages, 8vo. Leipzig, Akademische Verlagsgesellschaft, 1913.

Über neuere thermodynamische Theorien (Nernstsches Wärmetheorem und Quantenhypothese), Vortrag gehalten am 16 Dezember, 1911, in der Deutschen Chemischen Gesellschaft in Berlin, von Dr. Max Planck. 34 pages, 12mo. Leipzig, Akademische Verlagsgesellschaft m. b. H., 1912.

U. S. Geological Survey: Mineral Resources of the United States, Calendar Year 1912. Part 1, Metals. 1079 pages, 8vo. Washington, Government Printing Office, 1913.

Annuaire pour l'an 1914 publié par le Bureau des Longitudes avec des notices scientifiques. 502 pages, with appendices, 16mo. Paris, Gauthier-Villars, no date. Price, in paper, 1.50 francs.

Canada Department of Mines: Magnetic Occurrences along the Central Ontario Railway, by E. Lindeman. 23 pages, plates, maps, 8vo. Austin Brook Iron-Bearing District, New Brunswick, by Einar Lindeman, M.E. 15 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1913.

U. S. Weather Bureau: The Floods of 1913 in the Rivers of the Ohio and Lower Mississippi Valleys, Bulletin Z, by Alfred J. Henry, Professor of Meteorology. 117 pages, illustrations, plates, maps, quarto. Washington, Government Printing Office, 1913. Price, 40 cents.

Harrison Safety Boiler Works: Cochrane Separator Catalog No. 550, Introduction and General Description. 36 pages, illustrations, 8vo. Philadelphia, Harrison Safety Boiler Works, 1913.

A Legislative Program to Restore Business Freedom and Confidence. An address delivered before the Illinois Manufacturers' Association at the Hotel LaSalle, Chicago, January 5, 1914, by Samuel Untermyer, of New York. 40 pages, 8vo. New York, 1914.

Mauro and his Rôle in Spanish Politics: Synthetic and Documental Exposition of the Ideas and Work of the Conservative Leader by an Impartial Spectator. English edition. 36 pages, 12mo. Madrid, Imprenta Alemana, 1913.

Canada Department of Mines: The Production of Cement, Lime, Clay Products, Stone, and other Structural Materials in Canada during the Calendar Year 1912, by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 64 pages, 8vo. Ottawa, Government Printing Bureau, 1913.

U. S. Bureau of Mines: Technical Paper 54, Errors in Gas Analysis due to Assuming that the Molecular Volumes of all Gases are Alike, by George A. Burrell and Frank M. Seibert. 16 pages, 8vo. Washington, Government Printing Office, 1913.

U. S. House of Representatives, 63rd Congress, 2nd Session, Report of the Committee on Mines and Mining on Radium. 18 pages, 8vo. Washington, Government Printing Office, 1914.

An Experiment in the Compilation of Mortality Statistics, by Louis I. Dublin, Statistician, Edwin W. Kopf, Chief Clerk Statistical Bureau, Metropolitan Life Insurance Company, New York. 9 pages, 8vo. Reprinted from the Quarterly Publications of the American Statistical Association, December, 1913.

The Full-time Health Officer and Rural Hygiene, Address delivered at the Conference of State Health Officers, Louisville, Ky., December 8, 1913, by Louis I. Dublin, Ph.D., Statistician Metropolitan Life Insurance Company. 8 pages, 8vo. New York, 1913.

Possibilities of Reducing Mortality at the Higher Age Groups, Read before the Section on Vital Statistics, American Public Health Association, Colorado Springs, September, 1913, by Louis I. Dublin, Ph.D., Statistician Metropolitan Life Insurance Company, New York, 1913. 10 pages, 8vo.

CURRENT TOPICS

An Electric High School.—Electricity from a government power-house furnishes heat for the new high school at Rupert, Idaho, in the centre of the Minidoka Irrigation Project, according to a statement just issued by the United States Bureau of Education. This is said to be the first case on record where a large building has been heated entirely by electricity. The use of electric current for heating and for a variety of other purposes in the new building has caused it to be known as "The Electric High School."

The system of electric heating installed in the Rupert High School is remarkable for its simplicity. The usual arrangement of hot-air pipes, flues, etc., has been adhered to, but instead of furnaces or steam coils a battery of electric heat units, similar to those used in electric baking ovens, provides the heat. Twenty 18-kilowatt units are installed in pairs, each pair with a separate control of the current from a switchboard in the principal's office. Thus the principal can regulate absolutely the amount of current used. An emergency switch in the principal's office may also be used to cut out all current from the entire building—heat, light, power, etc.

Electricity is put to work everywhere in the Rupert building. A 10-horsepower motor, besides driving the ventilating fan, supplies all the power needed for the lathes and saws in the manual training department. An electric water heater supplies the hot water for the domestic science department, for the shower baths, for the various lavatories, and for the science rooms. In the domestic science room each girl of a class of 20 has her individual electric disc stove and all necessary cooking utensils. This room will also have an electric range and other electric equipment for serving cafeteria lunches on a large scale.

In the science laboratories electric hot plates are provided for evaporation purposes, and each pupil will have an electric appliance to take the place of Bunsen burners.

The electric lighting system includes an auditorium set with stage lights and switch control equal to those of the best theatres. The lighting and other equipment have been planned with the idea of making the high school building a model "community centre."

The entire electric equipment was planned by local electricians with the assistance of U. S. Government engineers on the Minidoka Project. The government supplies surplus current from its own power-house, 14 miles above Rupert, at a cost low enough to compete with coal. It is estimated that the cost of heating the new high school by electricity will be \$1760 per year. Coal might have been used at a cost of about \$1000, but the use of electricity saves

the wages of a fireman at \$75 per month, and the cost of installing the electric system was \$3000 less than for any other system of heat—the interest on this investment being saved annually. It is therefore believed that the use of electric heat in the Rupert High School, besides being a great convenience, will prove a real economy.

Theory of Vulcanization. D. SPENCE and J. YOUNG. (*Kolloid-Zeits.*, xiii, 265.)—Further experimental evidence is given in support of the author's view that vulcanization is a chemical process. It is shown that there is no "critical temperature": Vulcanization takes place at all temperatures, and the acceleration due to rise of temperature is of the same order as in other chemical reactions. Comparative experiments with caoutchouc, balata, and gutta-percha showed that they all yield the same final product, containing 32 per cent. of combined sulphur and exhibiting the same physical properties. The differences between raw caoutchouc, balata, and gutta-percha must, therefore, be of a physico-chemical nature, and in accord with this view is the fact that as balata and gutta-percha become vulcanized they first acquire more and more the elastic properties of rubber; as vulcanization progresses the properties of the products gradually become more alike, until finally in all three cases a product having the characteristic properties of hard rubber is obtained.

Glass Containing Copper. A. GRANGER. (*Comptes Rendus*, clvii, 935.)—The glasses studied were those found in commerce having an acidity of 2.5 to 3.5 silicic acid. Blue is developed with high alkali content, as in glass of the formula: 0.75 sodium oxide, 0.25 calcium oxide, 0.05 copper oxide, 2.5 to 3.5 silicic acid, the acidity having no appreciable influence on the color within the limits assigned, except that lower silica content tends to allow a surface deposition of metallic copper when the melt is run into a cold metal mould. This reduction to metal by rapid cooling is incidentally suggested as a method of obtaining copper-red. Replacement of calcium oxide in the above formula by lead oxide, zinc oxide, barium oxide, or magnesium oxide does not affect the blue tint, but magnesium oxide is considered unsuitable for the manufacture of glass. Potassium oxide may be substituted for sodium oxide. Aluminum oxide may be added up to 0.1 equivalent, but above that amount produces a greenish glass. Boric acid also tends to give a green coloration and renders the glass less transparent; it is stated that boric glass some millimetres thick is almost opaque. If the alkali content of a blue glass be reduced, and the heavier oxides increased, the blue proportionately decreases and the tendency to green increases. Increase of copper oxide above 0.05 acts in the same way. The production of a green without a trace of blue, however, is difficult within the commercial limits of possibility unless iron oxide be added. A formula for such a glass is: 0.7 Na₂O, 0.15 CaO, 0.15 CuO, 0.0 to 0.25 Al₂O₃, 1.0 B₂O₃, 2.5 SiO₂.

Third Annual Mining Exhibition, under the auspices of the Chemical, Metallurgical, and Mining Society of South Africa, will be held in the Volunteer Drill Hall, Johannesburg, beginning May 19th, and closing May 29th.

The scope of the exhibition will be on much the same lines as in previous years,—*i.e.*, chemical, metallurgical, and mining apparatus and devices for laboratories, works, and mines; models of apparatus for similar purposes; plans, diagrams, etc., of mines, works, plants, machinery, and apparatus; safety and rescue apparatus and appliances; and specimens of crude and manufactured mineral or other natural products of South Africa.

The exhibition is primarily for the benefit and information of those engaged and interested in mining work and mineral products.

No charge will be made for the exhibition of natural products by farmers or prospectors, or for models or apparatus exhibited by mine employees or inventors.

Commercial firms desirous of exhibiting machinery, apparatus, etc., will be charged for the space occupied.

The usual arrangements for exhibitions with regard to customs duties and railway rates will be made.

Further information may be had by applying to Fred Rowland, Secretary, Johannesburg, South Africa.

International Exposition of the Book Industry and Graphic Arts.—An exhibition of the book-making industries will be held in Leipzig, Germany, from April to November of the present year, to commemorate the 150th anniversary of the founding of the Royal Academy for the Graphic Arts.

Lithography, photography, wood carving, stereotyping and electrotyping, printing processes, bookbinding, and all other branches of the graphic arts will be included.

The exhibits will be divided into sixteen groups, consisting of sixty-three classes. Considerable space will be devoted to the department of education, where plans and models of school buildings will be shown, as well as drawings, examination papers, and other work by students.

Detailed information may be had by addressing the management.

Structure of Diamond. W. H. BRAGG and W. L. BRAGG. (*Nature*, xci, 557.)—The new methods of investigation were applied, involving the use of X-rays to the case of the diamond, and there was obtained a knowledge of its structure, which is extremely simple: Each carbon atom has four neighbors at equal distances from it and in directions symmetrically related to each other. The directions are perpendicular to the four cleavage or (111) planes of the diamond, therefore parallel to the four lines which join the centre of a given regular tetrahedron to the four corners. The elements of the whole structure are four directions and one length, this

being 1.52×10^{-8} cm. If the structure is observed along a cleavage plane, it is seen that the atoms are arranged in parallel planes containing equal numbers of atoms, but separated by distances which alternate and are in the ratio of 3:1 (viz., 1.52 and 0.51 each $\times 10^{-8}$ cm.). It is a consequence of this arrangement that no second-order spectrum is reflected by the (1.1.1.) planes, although spectra of the first, third, fourth, and fifth orders are found. It was this fact that suggested the structure here described. Several tests may be applied and all are satisfied. Zincblende appears to have the same structure, but the (1.1.1.) planes contain alternately only zinc and only sulphur atoms. In this way the crystal acquires polarity and becomes hemihedral.

Paper Dust Explosion. ANON. (*Times. Eng. Suppl.*, Dec. 3, 1913, 24.)—Much interest has been aroused in France by M. Bonn's report on an explosion of paper dust which occurred at a factory at Lille in May last. Although similar explosions of carbonaceous dusts, such as flour, sugar, starch, and cork, have been recorded in France and elsewhere, this appears to be the first occasion in which it has occurred with paper dust. At the factory referred to the edges of paper rolls are ground, and the resulting dust is collected in a dust chamber which is periodically emptied. The explosion occurred when emptying the chamber. A sample of the dust was sent to the experimental station at Liévin and tested, with the result that it was shown to be extremely inflammable, and capable of producing an explosion in a closed space when mixed with air and exposed to flame; the degree of inflammability being equal to that of finely-powdered Liévin coal, containing 30 per cent. of volatile matter.

The Melting-Point of Coal Ash. E. J. CONSTAM. (*Z. Ver. Gas. und Wasserfachmänner in Oesterr. Ung.*, Oct. 15, 1913.)—To determine the fusing-point of ash, equilateral pyramids, obtained by making a paste, moulding and drying, were heated in a tube in an electric furnace. The decrepitation, intumescing, and fusion of the pyramids of ash, and the temperature of fusion, can be optically observed, as the tube, closed at one end, has the properties of an absolutely black body. It appears that: (1) The percentage of ash in a coal has no influence on the melting-point of the ash; (2) the melting-point of the ash is a characteristic of the coal seam; (3) the melting-point of coal ash is in general not affected by coking or the temperature of coking. The investigations gave melting-points ranging from 1150° to 1700° C. (2100° to 3090° F.), and the author classifies coal ash into the following groups, viz., (1) readily fusible—below 1200° C.; (2) fusible—between 1200° C. and 1350° C.; (3) difficultly fusible—between 1350° C. and 1500° C.; (4) very difficultly fusible—between 1500° C. and 1650° C.; and (5) refractory—above 1650° C. Chemical analysis shows that, as regards the samples examined, lime, iron, and sulphur (pyrites) lower

the melting-point, while alumina raises it. Therefore, if an ash is found too readily fusible, the addition of alumina or clay, or the admixture of the coal with another coal having a difficultly fusible ash, should serve to give an ash having the required fusing-point. It is shown that it is necessary also to pay greater attention to the amount of slate in the coal; for, although slate is generally refractory, it becomes the core of large lumps of clinker which interfere with the working of the furnaces. With regard to the uses of coal, the following limits for the melting-point of the ash are named, viz., coke for central heating plant, above 1300° C., anthracite for central heating plant, above 1400° C., boiler coal, above 1400° C.; locomotive and producer coal, above 1500° C.; or fluxing at about 1200° C. Gas coal should have ash with a fusing-point not below 1300° C., and should be as free as possible from pyrites and slate. The author holds the opinion that the determination of the melting-point of the ash will become an important criterion, like the determination of volatile matter and of the proportion of ash, in the valuation of coals, especially gas coals.

The Utility of Airships in the Treatment of Tuberculosis.

ANON. (*Sci. Amer.*, cvii, 9, 175.)—Dr. Flemming, a prominent medical authority, at a meeting of the Berlin Aëronautical Association lectured on the beneficial effects of high altitudes on tuberculosis. He pointed out that 15 minutes' exposure to the sun's rays during an airship flight at high altitude meant certain death to the tuberculosis bacilli.

Sugar Cane Grinding. I. H. MORSE. (*Louisiana Planter*, 1, 383.)—To make sugar manufacture profitable in Louisiana under the present conditions, due to the abolition of the sugar duty in the United States, it is advised that the upper part of the cane, which has a much lower sugar content than the middle and bottom parts, should not be ground, but should be used for the production of table syrup, or be utilized as a stock fodder. In Louisiana the cane contains approximately 13.50 per cent. of sucrose in the lower part and 8.0 per cent. in the upper part. By grinding all the cane, the average sucrose content of which is 11.68 per cent., there would be a loss under the new conditions, whereas by crushing only the lower part, which represents about two-thirds of the total weight of the stalk, there would be a profit of about 60 cents per ton.

Action of Hydrogen Peroxide on Aluminum. DROSTE. (*Chem. Zeit.*, xxxvii, 1317.)—Aluminum is slowly attacked by hydrogen peroxide; 0.2 gramme, dissolved in 250 c.c. of a three per cent. solution, in 45 days forming insoluble aluminum hydroxide. No hydroxide remains in colloidal solution; therefore, aluminum vessels are not suitable for liquids which can yield free oxygen or ozone.

Paving Brick from Blast-Furnace Slag. F. G. BOLLES. (*U. S. Consular and Trade Reports, Min. and Eng. World*, Nov. 1, 1913.)—This industry is developed in the north of England, at Middlesbrough. The bricks are manufactured by the following process: A suitable site is selected near the blast furnaces, from which a railroad carries the slag to the moulding machine. The car which carries the slag is of plate steel with a firebrick lining, the top is covered over with a removable cap, in the centre of which is a hole about 18 inches in diameter, through which the slag is poured when the car is filled at the furnace. At the bottom of the car is a tap similar to those used on blast furnaces. The car of molten slag is run alongside the wheel carrying the moulds and forming the moulding machine, the trough to the tap extending over the moulds; the clay plug in the tap is knocked out and the molten slag runs into the mould. As soon as it is filled, an operator, by means of a hand-wheel mounted upon a sheet-steel heat deflector and connected through rods and mitre gears to the centre of the moulding wheel, turns the latter so that the next mould comes under the flow of hot slag, and so on till all the moulds are filled. By the time that the wheel has made a quarter revolution the cast bricks have sufficiently cooled so that they may be dropped out of the moulds by knocking off the catch which holds the bottom in place. As soon as they have dropped to the ground they are carried to the adjoining gas-heated annealing furnaces. These furnaces hold approximately 1100 bricks at one charge. The heat retained in the bricks when they are placed in the furnace, together with a very small amount of fuel, again brings them to a cherry red, and as soon as the furnace is filled it is closed and allowed to cool gradually, 24 hours usually being required before the bricks are removed. The capacity of the slag car is approximately $3\frac{1}{2}$ tons, from which 360 to 400 bricks are made. The bricks weigh about 14 pounds each. These bricks are very efficient for street paving, and are being exported to the United States, Canada, and many other countries.

Influence on Life of Tungsten Lamps by Enclosure in Outer Globes. G. SUNDÉN. (*Elektrotechn. Zeitschr.*, xxxiv, 992.)—It is found that the enclosure of tungsten filament lamps within a clear outer globe increases the temperature external to the lamps, and that this may lead to a diminution in useful life. A lamp with an external temperature of 20° C. had a life of 2000 hours, but a similar lamp running in a temperature of 200° C. lived only 40 hours. On the other hand, a water-cooled lamp, with a surrounding temperature of 2.5° C., gave better results, remaining quite clear at the end of the test and showing no diminution in candle-power, whereas the bulbs of the other lamps were distinctly blackened. It is therefore advocated that lamps should not be enclosed in outer globes, especially frosted ones, which materially increase the surrounding temperature.

Quality of Pure Rubber from Various Sources. ANON. (*Bull. Imp. Inst.*, xi, 375.)—*Ceylon*.—Samples obtained from trees tapped at intervals of from three to seven days contained a little more caoutchouc (96.0 to 96.3 per cent., referred to the dry-washed rubber) than those from trees tapped every day or every other day (95.7 or 95.4 per cent. of caoutchouc respectively). *India*.—In six specimens of crêpe rubber from the Mergui District, Burma, the percentages of resin and protein were somewhat higher than is usual in the best plantation Para, and three of the samples yielded an excessive quantity of ash. The two best specimens were of very good quality and contained 94.3 and 93.6 per cent. of caoutchouc respectively (on the dry-washed rubber). *Southern Nigeria*.—Two samples of biscuit rubber from Sapele, Central Province, were satisfactory, both in composition and physical qualities. *British Guiana*.—A sample of biscuit rubber from trees four and one-half to five years old, grown at Issorora, Northwest District, was equal in composition to plantation Para from the East, but was somewhat deficient in strength. When the trees become older the rubber should be of excellent quality. *Papua*.—The rubber exported from Papua up to the present has been obtained from *Ficus Rigo* and an unidentified vine; but there are over 4000 acres planted with *Hevea brasiliensis*, and some of these trees have recently been tapped. A sample of the first consignment of Para rubber, from Sogeri, proved quite equal to the highest grades of plantation Para, both in composition and physical properties.

Sulphur Deposits in New Zealand. ANON. (*Board of Trade Journal*, Nov. 6, 1913.)—Important works in connection with the sulphur deposits of White Island, a mountain top jutting out of deep water in the Bay of Plenty, are to be undertaken, and a company has been formed for this purpose, although operations on the island have been carried on for the past eighteen months. The first shipment of sulphur has been made, which contained 75 to 80 per cent. of pure sulphur. The company expects to have facilities for raising, within the next few months, pure sulphur to the extent of about five hundred tons per month.

Influence of Temperature and Pressure on the Volatility of Zinc and Cadmium. T. K. NAIR and T. TURNER. (*Chem. Soc. Trans.*, ciii, 1534.)—In attempting to remove zinc by volatilization *in vacuo*, on a practical scale, from a charge of about 150 kilogrammes of a zinc alloy, it was found that small imperfections in the vacuum considerably diminished the rate of volatilization. Laboratory experiments with zinc and with cadmium showed that at a given pressure appreciable volatilization does not occur until a definite critical temperature is attained, but from this point the rate of volatilization increases with rise of temperature independent of the initial pressure. A rise of temperature to about 90° C. above that

required for 10 per cent. volatilization will increase the volatilization to 100 per cent. in the same period of time. The critical temperature is raised by gaseous pressure; air has a somewhat greater effect than carbon dioxide, and the latter somewhat greater than hydrogen, but at low pressures the differences are negligible in practice. Down to about 50 mm., each millimetre reduction of pressure causes a small but equal lowering of the critical volatilization temperature, but at lower pressures the effect is much more marked, and when a perfect vacuum is nearly attained a reduction of pressure of one millimetre has an effect 70 times greater than at high pressures. It was observed that zinc is oxidized to a much greater extent by air in motion than by still air.

Conductivity of Copper-Tin Alloys. N. A. PUSCHKIN and A. V. BOSKOV. (*J. Russ. Phys.-Chem. Soc.*, xlv, 746.)—The curves showing the variation of (1) the specific resistance and (2) its temperature coefficient with the composition of copper-tin alloys indicate the existence of a definite compound, Cu_3Sn . The low value of the temperature coefficient, corresponding with the composition Cu_4Sn , indicates the formation, not of a definite compound, but of a solid solution. The addition of tin to copper causes a very rapid increase in the resistance, while copper produces but little change in the resistance of tin.

Early Iron Manufacture in Staffordshire. T. TURNER. (*Engineering*, xciii, 643.)—The analysis of a "ham-bone" from the Little Aston forge showed no graphite, 0.31 per cent. combined carbon, 0.05 per cent. silicon, 0.31 per cent. phosphorus, 4.93 per cent. sulphur, and no manganese. The high sulphur and low carbon and silicon are noteworthy in a metal which was made at least two centuries ago. The probable method of manufacture is also described.

French Hydro-aéroplane Experiments. ANON. (*Sci. Amer.*, cvii, 9, 175.)—During the recent manœuvres of the French fleet in the Mediterranean, the warship *Foudre* was fitted out to carry hydro-aéroplanes. This is easier to accomplish than in the case of ordinary aéroplanes, as there is no launching platform needed from which the fliers start. An overhead crane on the vessel takes up the fliers as they leave the hangar and drops them overboard. The first Nieuport monoplane of this kind, piloted by Ensign Delage, was quite successful. It is of the three-phase type and carries a 100-horsepower Gnome motor. On one occasion the aéroplane went overboard in rough water, and made several flights above the fleet. One part of the fleet represented the enemy in the manœuvres, and the aéroplane observed its position and brought back a very correct report. Some of the flights with one passenger aboard lasted for three hours, flying above Toulon and the harbor and along the coast.

Corrosion of Nickel, Chromium, and Nickel-Chromium Steels.

J. N. FRIEND, J. L. BENTLEY, and WALTER WEST. (*Engineering*, xciii, 753.)—Disks were prepared of carbon steels, to serve as standards, of nickel steels, of chromium steels, and of nickel-chromium steels, each 0.7 cm. thick and 2.8 cm. in diameter. These disks were kept nearly immersed in tap-water for 64 days, in sea-water for 60 days, in 0.5 per cent. sulphuric acid for 60 days, in 0.5 per cent. sulphuric acid for 53 days, and they were exposed to alternate wet and dry tests for 52 days. The acceleration tests in 0.5 per cent. sulphuric acid gave misleading results, and the two standard steels, which showed practically equal corrosion in all the other tests, showed 100 per cent. deviation with 0.5 per cent. sulphuric acid, and with the other steels there were remarkable differences. In some cases there were indications of galvanic action in the chromium and nickel steels in the acid tests, and no chromium nor nickel passed into solution, showing that these elements were the constituents of the cathode. The resistance of chromium steels to corrosion in salt water suggests the use of this metal for ship-building. Nickel steels show marked resistance both to acid and neutral corrosive solutions, the resistance increasing with increased nickel content.

New Method of Fermentation of Beetroot Juices and Molasses. MARTINAUD. (*Bull. Assoc. Chemi. Sucr.*, xxxi, 29.)—In the manufacture of alcohol from beetroots, the juice is commonly acidified with sulphuric acid prior to fermentation, in order to check the development of foreign organisms. The author recommends the use of sulphurous acid instead of sulphuric acid. If beet juice is treated with sulphurous acid (*e.g.*, 0.53 gramme SO_2 per litre), and yeast is added, fermentation commences rather slowly, because most of the acid remains in the free state. If, however, the sulphited juice is mixed with about one-third of its volume of juice already in vigorous fermentation, a rapid and satisfactory fermentation of the whole is ensured. A part of the juice fermented in this way may be used for starting fermentation in fresh sulphited juice; the yeast remains pure and may be employed for successive fermentations without further treatment. The same procedure may be applied to the fermentation of molasses.

Electrolysis of Iron and Lead in the Soil. GIROUSSE. (*Comptes Rendus*, clvii, 705.)—Electrodes of iron and lead were placed in wooden boxes coated with paraffin wax and filled with earth kept moist; with the circuit open, there was a difference of potential of 0.15 to 0.2 volt from the lead to the iron. Corrosion of both metals began when the current passed, and its extent was proportional to the quantity of electricity passing and independent of the potential difference. The contact resistance between lead and soil was much greater than that between iron and soil, and under given conditions iron was corroded much more rapidly than lead.

Formation of United States National Radium Institute. C. L. PARSONS. (*U. S. Bureau of Mines*, Oct. 23, 1913.)—Dr. James Douglas and Dr. Howard A. Kelly, of Johns Hopkins University, Baltimore, have bought 27 claims of mining land in Paradox Valley, Col., the greatest radium-bearing ore deposit now known. A National Radium Institute has been formed by the above and others to work the carnotite deposits on the claims under the supervision of the Bureau of Mines, which is said to have devised a new and cheaper method of extracting radium chloride. None of the radium extracted will be for sale, but the whole will be used in special clinics for the treatment of cancer in the Memorial Hospital, New York City, and in Dr. Kelly's hospital in Baltimore.

Corrosion and Preservation of Metals. F. LYON. (*Steamship*, xxv, 322.)—Corrosion, the chemical decomposition of metal, is due to difference in electric potential between the metal and the liquid that wets the surface. Metals that are absolutely dry do not corrode. The state of internal stress of material depending on the mechanical work and heat treatment it has received influences the manner and rate of its corrosion; the more seriously stressed material corrodes more rapidly. A bent plate or angle corrodes more rapidly in and near the bend than the straight portion. Tubes corrode more rapidly at the bends and flanges. Whereas copper alloy castings seldom give trouble, they greatly increase the rate of corrosion of less electro-positive material, such as steel, if in good metallic contact with it. It is customary in such places to secure plates of zinc to the steel in order to protect it. The writer fails to see the value or necessity of this practice for the following reasons: (1) The zinc corrodes rapidly and becomes covered with a coating of zinc oxide, which is always found to be electro-negative to steel; (2) in no case has he found steel connected to zinc corrode less in thirty days than when not so connected; (3) a proper coat of paint between the alloy and steel surfaces will give efficient protection.

Galvanizing, electroplating, and other such processes as means of protection to steel when continuously immersed are dangerous, and not to be recommended. It is deemed sufficient to provide the most homogeneous material possible, both chemically and physically, and to paint it in a proper manner. The painting of metal is discussed. With regard to boilers, condensers, etc., it has been definitely proved that any water showing 3 per cent. alkalinity with calcined sodium carbonate is non-corrosive to steel up to 422° F. If the alkalinity falls to from 1.8 to 2.5 per cent., bad pitting ensues. Much more harm is done by attempts to produce the correct amount of alkalinity in waters than by the small amount of acids which may ever enter an average boiler. The Cumberland method of preserving the interior surfaces of water-carrying pipes and circulating systems, by raising the potential of the water to a value higher than at any point in the system, appears to be the only practicable method, and gives excellent results when properly installed and attended.

Surface Combustion. JAMES A. SEAGER. (*Steam*, xiii, 43.)—It is interesting to note that this system is being applied to a considerable number of industrial processes by the Bonecourt Surface Combustion, Ltd., of Westminster, London, England. Porous diaphragms of refractory material, through which the gas and air are passed, the gas burning without flame, are now used for such purposes as boiling sugar solutions, heating the dies used in cable factories, drying the varnish and stampings used for electrical machinery, and other purposes. For cases where the boiling of solutions or similar operations are required, the Bonecourt diaphragm is in itself far more efficient than any other gas heating device. It is stated that the consumption of gas is reduced by over 50 per cent., as compared with other methods.

For example, a well-known firm of confectionery manufacturers in London has employed these diaphragms in its works for boiling and concentrating sugar solutions, and has thereby effected a saving of more than half of the gas previously required for the same operations. Furthermore, the cleanliness, safety, and ease of operation of this method of heating are great improvements over existing practice. These diaphragms are made in circular or square form, in sizes ranging from 4 inches to 13 inches, while strip formations are made in 6 inches by 3 inches, 10 inches by 8 inches, and 12 inches by 3 inches. In order to supply the required air under pressure, a fan is installed giving a delivery pressure of about 6 inches water gauge, the pressure at the diaphragms being from 2 inches to 3 inches water gauge. Any of the standard fans used for blowing forges, etc., are suitable for this purpose, and the adjustment for obtaining the correct proportion of gas and air at the diaphragm is simple. In order to effect the preliminary heating of the diaphragms, a by-pass is taken off the gas supply; this by-pass is shut off directly the flameless combustion is started. The Bonecourt diaphragms reach their full heat within a few seconds of lighting up, and soon become cold after the gas supply is shut off. By this system of combustion, in which the gas is burnt without flame, over 70 per cent. of the heat contained is converted into radiant energy at the surface of the diaphragm. This is the secret of the high efficiency secured, as it is well known that the gas flame is an efficient medium for heating metallic surfaces, such as the vessels in which solutions are to be boiled, owing to the insulating layer of cool air which forms between the flame and the surface of the vessel. In the case of the diaphragm, a large percentage of radiant heat is quickly absorbed by the vessel and is transferred with high efficiency to the liquid to be heated.

Safety in Railroad Shops. ANON. (*Railway Master Mechanic*, xxxviii, 77.)—In September, 1910, the Pennsylvania Railroad employed the experts of one of the large accident liability insurance companies to make a thorough inspection of each shop plant. In consequence, it was deemed advisable to make the work of safety

inspection a permanent feature and organize a safety movement to cover road and yard as well as shop conditions over the entire system. Safety committees were appointed in January, 1911, for each superintendent's division, and for each shop for repairing engines and cars. These committees have made 17,333 formal recommendations, 13,861 having been complied with at a cost of \$413,525.23. During the six months ended June 30, 1913, 3209 safety recommendations were made, 2390 being complied with at a cost of \$75,361.97.

In addition to the divisional safety committees, a mechanical engineer was engaged for the specific purpose of making inspections at the various shops. During the year ended June 30, 1913, 58 general inspections and 15 special inspections were made. Usually the first inspection results in attention being called to all hazards, and the following inspections are made to see that the recommendations for the installation of safety devices are complied with.

One of the results of all this detailed attention to safety is that \$99,753 has been spent for safety guards—mainly in shops. Practically all machines and dangerous conditions are now guarded. But the real result is that serious accidents to shop employes have been reduced from 5.4 per 1000 employes in 1911 to 3.2 in 1912. In 35 out of 46 shops, where more than 500 men are employed, the number of serious accidents per 1000 men has been reduced by from 5 to 70 per cent.

International Electrical Exhibition, Barcelona, 1915.—An exhibition of electric industries will be held in Barcelona in 1915. The Spanish Government has given the enterprise its official sanction, and has promised financial support. The municipality and other organizations in Barcelona have guaranteed important subsidies. Two millions of dollars have been promised by the Town Council. There is certain to be great activity in the Spanish electrical industries during the next two years. Power stations for the development of electricity in the waterfalls of the Pyrenees and elsewhere are being erected. It is expected that by the time of the opening of the exhibition, 300,000 horsepower will be transmitted to Barcelona, and will be obtainable, for commercial purposes, at very low rates.



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ADVANTAGES AND DISADVANTAGES OF RESERVOIR
STORAGE.*

BY

W. P. MASON,

Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.,
Member of the Institute.

At the outset it must be admitted that the advantages of water storage are many and the disadvantages but few. In those days when the expression "stagnant water" carried with it all sorts of ill-defined fears, the opponents of storage were easy to find, and their enthusiastic statement that "abundance of light and air is essential to the proper conditioning of water for human consumption" received very general support. He who drank of the rapid stream was accounted greater in wisdom than he who selected a less aërated supply.

It is now almost trite to say that still water, rather than running water, purifies itself the better, and it equally lacks novelty to point out that the more rapidly a stream flows, the sooner is its load of pollution delivered to the thirsty consumer. In that connection, let it be said that a great deal more depends upon the number of hours required for stream flow than upon the distance in miles between the intake and the source of pollution, and a

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concise statement giving information as to time of flow should appear in a report covering the sanitary survey.

Stagnation has its disadvantages, of course. Increase in color naturally follows if water be permitted to long remain in contact with a muddy bottom loaded with soluble extractive matters. Not only is damage to the water's physical appearance a result of such contact, but the material passing into solution is likely to furnish abundant food for those minute forms of life which carry objectionable tastes and smells to many public waters.

To the layman's ear the word "stagnant" has a most unpleasant sound, intimately associated with the production of disease; and yet its origin is innocent enough, viz., "stagnum," a piece of standing water, not running in a current or stream.

Pools so overloaded with vegetable growth, both dead and alive, as to be unfit for human drinking are plenty and they are commonly stagnant, but the ill-favored word does not properly apply alone to those; it is just as applicable to a water of crystal clearness resting upon a bed of sand.

The condition of "standing water" just referred to,—namely, that of being overstocked with vegetable growths,—is practically the only one toward which objection can point when considering the *pros* and *cons* of reservoir storage.

The word "vegetable" is here to be taken in its broad sense, as it should include not only those growths which would be recognized by the public at large, but also those of the minute world as well, which latter constitute one branch of that lake life known as "plankton."

As an instance of excessive overgrowth, a small lake could be named which is so loaded with dense vegetation that decay gets ahead of new growth, and the use of its water is productive of temporary diarrhoea. It is a stained water, but its color is not to be considered as a measure of its objectionable qualities for table use, as many waters of much darker tint are of excellent quality for such purpose. Color and fitness for drinking bear no relation to each other.

It is true that colorless waters are now demanded by the people, and "meadow teas" are growing in disfavor, but that

change in public opinion is of recent date and is not based upon established hygienic grounds.

The deepening in color of the lower layers of a water stored upon an unclean bottom; the encouragement of growths of small organisms producing taste and smell by reason of an accumulation of extracted food suitable for their development; and a deficiency in dissolved oxygen in the bottom levels, constitute the sum of objections that can be raised to the impounding of water, and they are much more than balanced by the advantages that accrue from such storage.

The pollution from shore drainage that reaches a reservoir water is likely to be naturally much smaller in quantity than that received by a flowing stream; nevertheless, very serious pollution may occur in concentrated form, even when the efforts of the caretaker are the most earnest. Thus, the writer has seen numerous loads of stable manure spread upon the very steep banks of a small, cup-shaped distributing reservoir. The intention in this case was good, and much pride was taken in the fine lawns of the water-works park, but a better choice of fertilizer could have been made for such a location.

It is entirely possible to protect a reservoir, and to a great degree the water-shed also, if careful policing of the district be established. Country towns situated upon the banks of streams tributary to the reservoir are the sources of greatest danger, and an earnest effort should be made to remove all privies, manure heaps, farm yards, refuse dumps, and other sources of pollution from draining into the stream or any of its feeders. This is sometimes difficult to accomplish completely, but a high degree of thoroughness can be attained by suitable and tactful management.

Board of health rules are expected to cover care of public water-sheds, but rules and laws will not enforce themselves, and the city official is commonly at a distance and more interested in the distribution system than in that of collection. The most simple arrangement would seem to be to appoint a local physician in each town or village upon the water-shed as the sanitary inspector for that particular district, and to give him authority to employ an intelligent laborer as a sub-inspector to do the necessary work under his direction.

The writer has found this arrangement both efficient and cheap. In one noteworthy instance, besides caring for the sources of pollution noted above, the sub-inspector's duty included the daily patrol of a mile of railroad track which ran along the border of the reservoir. This question of possible danger from railroad pollution has but recently been recognized. Although it is always well worthy of consideration, there is no question but that it greatly varies in importance with change in topography, soil, or season. Rocky, steep slopes are easily washed by the rain, and frozen embankments naturally fall into the same classification, while flat road-beds and sandy soils offer better chances for polluting material to be disposed of by natural methods.

Whatever the character of the road-bed, it should be the sub-inspector's care to remove all night-soil dropped from passing trains, and he should exercise greater vigilance in winter than during summer.

The physician-inspector would be in a position to know of cases of disease, such as typhoid, in his district and, being so informed, could take proper precaution against contamination of the public water, which act on his part would be of vastly more practical value than a location of the trouble by some sanitary commission after an epidemic was well under way.

The greatest responsibility borne by the inspector, however, would be during periods when gangs of laborers were employed at construction work within the limits of the water-shed. Should the workmen be many and the time of their remaining be two weeks or more, nothing short of incineration of all camp waste and night-soil should be demanded, and the utmost care should be taken that sanitary instructions were carried out to the letter. A Woodruff pit, which can be constructed in a few hours, would be suitable for a temporary camp; while, if something more permanent were demanded, a well-constructed incinerating furnace should be built.

When meadow lands are flooded, the extraction of food for plankton growth must of necessity take place, and we are forced to choose between stripping the proposed bottom or else depending upon the employment of some means of killing or removing the organisms that are likely to develop.

As to what could be done to rid a water of the odors due to algal and other growths, the outlook was not very hopeful previous to the appearance of the "copper sulphate process" proposed by Moore and Kellernan in 1904 (Bulletins 64 and 76, U. S. Bureau of Plant Industry).

The method of applying this chemical is simple enough, and its use is very efficacious. Bought in bulk, it can be had at about five cents per pound, and its distribution is readily secured by filling it into perforated buckets, or even bags, and towing the same by row-boat or launch over the reservoir surface.

Decided objection was raised against such a process of "disinfecting" a public water supply, and the opposition was especially marked in England, but the use of it is still with us and is likely to stay, for the reason that the "dose" is minute and is only occasionally required, that it is reliable in results, and that experiment has shown that it is not followed by the evil consequences predicted.

It must be remembered that it is not added to the water continually, but is used only at stated and widely-separated intervals,—namely, at those times when the "crop" of minute organisms has become so well grown as to produce objectionable effect upon the water.

Perhaps one reason why the "coppering" of reservoirs has led to so much criticism is because of the dead fish that are to be seen after the chemical has been applied. When considering this effect upon fish life, one should bear in mind that the "dose" has of necessity to be applied uniformly over the surface of the water, and each acre of such surface presumably receives the same amount, irrespective of the depth of water that the acre covers. As a result, the shallow parts of the lake receive temporarily a greater quantity of the sulphate, per cubic foot of water, than do those which are deeper; again, the entire quantity of chemical intended for the whole body of the lake is delivered to a few inches of its surface layer; therefore, until diffusion has taken place, fish which chance to swim into such water receive a very concentrated dose and are likely to be affected by it. Distribution is complete by the time the water reaches the public mains, and, moreover, the minute dose used has been more or less completely disposed of through its action upon the organisms for whose destruction it has been employed.

In a paper before the Section on Hygiene of the Eighth International Congress of Applied Chemistry, 1912, Kellernan presented the following data:

QUANTITY OF COPPER SULPHATE REQUIRED TO KILL VARIOUS FORMS OF ODOR-PRODUCING ORGANISMS.

Copper Sulphate Required, Expressed as Parts, per Million Parts of Water.

Anabæna .....	.09	Kirchneriella	5. to 10.
Asterionella .....	.1	Leptomitius .....	.4
Beggiatoa	5.	Microspora .....	.4
Chara .....	.2 to 5.	Navicula .....	.07
Cladophora	1.	Oscillatoria .....	.1 to .4
Cladothrix .....	.2	Peridinium	2.
Clathrocystis .....	.1	Scenedesmus	5. to 10.
Cœlosphærium .....	.3	Spirogyra .....	.05 to .3
Conferva .....	.4 to 2.	Ulothrix .....	.2
Euglena	1.	Uroglena .....	.05
Fragilaria .....	.25	Volvox .....	.25
Hydrodictyon .....	.1	Zygnema .....	.7

He adds a list of twelve genera of algæ that in his experience are causing trouble in reservoirs and ponds:

NUMBER OF OBSERVED CASES.

Anabæna	27	Conferva	56
Asterionella	9	Crenothrix	13
Beggiatoa	20	Fragilaria	19
Chara	26	Navicula	21
Cladophora	17	Oscillatoria	49
Clathrocystis	23	Spirogyra	43

Jackson claims that blue-green algæ will die if the water be "coppered" one part to five million. His dose for *Mellosira* or *Synedra* is one to two million, and he claims that the former gives no odor of growth, but only that of decay. He finds that coppering runs out certain forms of organisms and substitutes others by a sort of selective action, but those thus substituted are not likely to be odor producers; and he further notes that, while "bottom" or decomposition odors are easily shaken out by aëration, "top" odors, viz., those of growth, have to be removed by filtering out the organism, or killing them by copper sulphate, or both. In his opinion, filtration of either type is effective for removal of odors of growth, but he believes that

aëration would be worse than useless for living plankton, for the reason that the agitation would tend to mechanically release the oil causing the taste, which oil is not very easily oxidized.

Naturally the cost of treatment with sulphate of copper will depend in part upon the amount of the chemical that is to be used, which in turn is determined by the kind of organism that it is intended to kill; but it may be said that a mixed growth of *Meliosira* and *Asterionella* was removed from the Troy reservoir at an expenditure of 14.9 cents per million parts of water treated, labor included. The dose was one part of copper sulphate to 3,500,000 parts of water by weight.

In the article by Kellernan above quoted there are figures given indicating the safe limit for treating water with copper sulphate when certain fish are to be protected.

Copper Sulphate, Expressed as Parts, per Million Parts of Water.

Black bass	2.1	Pickereel .....	.4
Carp .....	.3	Suckers .....	.3
Catfish .....	.4	Sunfish	1.2
Goldfish .....	.5	Trout .....	.14
Perch .....	.75		

It must be noted that these figures assume a thorough mixing of the sulphate solution with the whole body of water. They would not hold for the unequal distribution and resulting local concentrations already mentioned.

In some reservoirs which have been formed by the extensive flooding of swamp bottoms there may develop objectionable growths of *Crenothrix*, a general term denoting an aquatic plant which at times gives much trouble because of its tendency to develop in the street mains and clog the pipes. It is often discovered quite unexpectedly, being dislodged by the current attending hydrant flushing or by the draft caused by fire engines. Dead ends are spots likely to harbor it, and its long rusty filaments have been mistaken for horse manure.

There are three types of the growth, each possessing the peculiarity of precipitating from the water in which it grows its own particular metallic hydroxide. By far the commonest of the three is *Crenothrix Kuhniana*, which demands iron for its development and which deposits large amounts of iron hydroxide as the result of its growth. The iron required for growth

must be in solution, and the quantity demanded would seem to be about 0.3 part of Fe per million.

In order that the iron may be in solution, we naturally would expect the dissolved oxygen to be low and the quantity of reducing agents, such as organic materials, to be high, and those are the conditions that we find in practice to be favorable to the development of the plant.

It is likely to be encountered in waters from swampy, peaty sources where dissolved oxygen is scanty and where the necessary iron in solution may be had. Driven wells in such localities frequently furnish it. Darkness favors its growth, and its development in city water-mains is often excessive, resulting in a material reduction of the carrying capacity of the pipes. The writer has some doubt about the "manganese" variety of *Crenothrix* being as rare as some think it is, he having found large quantities of manganese in a heavy Wisconsin growth. Beythien and others¹ have, moreover, noted that the presence of manganese in water directly favors the growth of the ordinary form of *Crenothrix*.

Beyond the mechanical stopping of street-pipes, *Crenothrix* is exceedingly objectionable to the laundry interests of the community, for the reason that its rusty filaments cause "iron stains" to appear upon white linen.

Removal of the iron by oxidation and filtration is the best guard against troubles due to *Crenothrix*.

It must not be sweepingly assumed that all the "plankton" life is to be rated as uniformly objectionable; quite the contrary, as a reasonable degree of it acts as a distinct help in maintaining the safety of natural waters. Thus we find "bacteria eaters," such as many kinds of ciliated infusoria, rotifers, daphnia and the like, feeding upon minute germ life, and doing so to our great advantage.

To quote from a translation by Kuichling: "The question is, what becomes of the great quantities of offal and excreta, the many remnants of decaying plants, the refuse of communities, and the finely-divided factory wastes of every description, which find their way into our streams, even under normal conditions, if a large portion thereof is not consumed by the aquatic detritus-eaters and the omnivorous fauna before settling to the bottom?"

¹ *La Technologie Sanitaire*, September, 1914, p. 61.

With a view to avoid the troubles arising from the undue growth of taste- and odor-producing organisms, the stripping of reservoir sites and the removal of a portion of the upper soil has been advocated and carried into practice. This, of course, entails very great expense when the surface to be stripped is at all extensive, as in the instance of stripping the Nashua reservoir supplying Boston. At Columbus, Ohio, such work cost \$159 per acre.

In their report upon the probable cost of stripping the surface soil from the Ashokan reservoir site, which is to hold the water supply for New York City, Messrs. Hazen and Fuller stated it would possibly reach the great figure of \$5,000,000.

In view of the expense of such treatment for large reservoirs, the question is pertinent, "Does it pay?"

At Holyoke, Mass., the annual water report for 1908 says: "Great care had been taken in cleaning and stripping the reservoir by removing all vegetable and organic matter, thus lessening to a minimum the food supply for supporting living organisms in the water. The thorough cleaning of the reservoir has not been wholly successful, as an aquatic plant known as 'Chara' has grown and flourished in the reservoir all summer and imparted to the water a taste and odor that made it unfit for drinking or even for cooking purposes."

Mr. J. M. Diven ("American Water Works Association," 1908) has had interesting and contrasting experiences with both stripped and unstripped reservoirs:

"The Elmira reservoir was as thoroughly stripped as possible; great care was taken to keep out the first washing from the drainage area and the muddy flood waters. There was little or no marsh land on the drainage area, the catchment area being seemingly ideal. The reservoir was clean and clear; on the sides the slopes were abrupt, and there was very little shallow water.

"At Charleston, S. C., the drainage area was largely swamp, and there was much decayed vegetable matter on all of the area drained, the water being decidedly peaty. The reservoir covered a large surface, was shallow, and absolutely unstripped or even cleared. Much of the land flooded was composed of black muck or decayed vegetable matter.

"In the first case (Elmira) the conditions were at the first

satisfactory and the water good for several years. But trouble from algal growth came in time and has steadily grown worse, in spite of strenuous efforts to remedy the condition.

"The second case (Charleston) was troublesome and unsatisfactory from the first, but has somewhat improved and promises to continue to improve."

The writer's experience leads him to advocate the expenditure of comparatively little money in the preparation of sites for large storage reservoirs, for the reason that, although thorough stripping will likely give immunity from algal growths for some years, yet freedom from the occurrence of taste and odor in the stored water may not last for long. Sooner or later there will be carried into even the most carefully cleaned reservoir enough food material to sustain a plankton growth of a density governed by the local conditions. Broadly speaking, an "old bottom" is better than a new one, because it is likely to contain less plant food; but the rule has many exceptions.

Even natural lakes are frequently seen "in bloom,"—that is, loaded with minute life,—and they so remain for a period during which their waters are not acceptable for domestic use. The character of the tributaries must be considered as well as the nature of the bottom of a proposed reservoir, for it is manifestly loss of money to improve the latter if the former can quickly replace much of what has been taken away.

For the sake of general appearances, if for no other reason, trees, shrubs and bushes should be removed. Dead, standing timber and fallen logs are most unsightly and are very likely to produce complaint from the visiting public. In other words, the reservoir site should be cleared and grubbed, with, of course, entire removal of every vestige of human habitation; but beyond that it scarcely pays to go. The portion of the flooded land lying between high-water and low-water marks should receive especial attention, for the reason that during the periods of its exposure it is capable, if uncared for, of presenting an unpleasant appearance and provoking adverse criticism; with the further objection that heavy weed growth may develop if it be long uncovered, which growth will contribute toward the production of taste and smell when the water again covers it.

In an instance where it was proposed to restore a dam that had been out of repair for over fifty years the writer advocated

the cutting off of the standing dead timber at the existing water level before closing the breach, in order to insure a better looking sheet of water when the reservoir filled. This was for appearances only, as all extractive matter had been leached out of the old vegetation long before.

Aëration, filtration, and the judicious, occasional use of copper sulphate constitute the processes at our disposal for combating the annoyance arising from algal growths, and their use will give greater satisfaction than the expensive stripping of reservoir bottoms, a treatment which was so frequently advocated in the past.

Dr. A. C. Houston, of the London Metropolitan Water Board, has undertaken some very extended researches upon the question of water purification as a result of storage. He found that in stored Thames water the death of typhoid bacteria took place rapidly, although the rate varied with the temperature of the water. In cold water they lived longer than in warm, and 50° F. seemed to be a critical point above which their mortality rate was much increased.

In his 7th Research Report, Houston states that typhoid bacilli lived in stored raw Thames water for the following lengths of time: At 32° F., five weeks; at 41° F., four weeks; at 50° F., three weeks; at 64° F., two weeks.

Even these figures do not tell the entire story. Put in more detail they read:

	At start.	1 week.	2 weeks.	3 weeks.	4 weeks.	5 weeks.
32° F.	103,328	47,766	980	65	34	3
41° F.	103,328	14,894	26	6	3	—
50° F.	103,328	69	14	3	—	—
64° F.	103,328	39	3	—	—	—

He concludes: "It is difficult to escape the belief that thirty days' storage of river water is tantamount to sterilization, so far as the microbes associated with water-borne epidemic disease are concerned."

When experimenting with an artificially-infected water to determine the effect of storage upon the typhoid bacillus, Dr. Houston felt that any error so introduced was upon the side of safety, because he had previously shown the "cultivated" typhoid organism to have a greater longevity than the "natural"

Bacillus typhosus. In his report he dwells at length upon the advantages to be derived from "adequately storing the *raw* impure river waters." Even if there were no economic reason for storing a river water before rather than after filtration, yet it would be well to follow that course, aside from any question of algal growths, for the reason that sedimenting silt greatly assists in bacterial removal. Placing the word "*raw*" in italics was, therefore, a matter of good judgment.

Dr. Houston adds: "I am well satisfied that a well-stored, rapidly-filtered water is likely to be safer than an unstored, slowly-filtered water."

It is possible to go even further than this, for one can see how dangerous it might be to deliver, directly to the consumers, the water of a small and apparently pure mountain stream. The dejecta of a single typhoid carrier would render so small a volume of water highly infectious, if no storage intervened, and an outbreak might follow, such as occurred at Plymouth.

Although Dr. Houston is doubtless sound in his judgment that a great measure of safety will result from four weeks' reservoir storage of a polluted water, yet we must be assured that the period of storage is real and not simply apparent; or, in other words, we must know that *all* of the water really does remain in the reservoir for the specified length of time before it is used for public consumption.

Where the inlet and outlet of a reservoir are near together, as is not uncommonly the case, it makes but little difference what the capacity of the total storage may be; the water simply slips in and out again with practically as little stay as though the reservoir were a standpipe.

If the lake be long, narrow, and deep, and all of its water be obliged to traverse its entire length before being taken for supply, then the conditions would appear ideal for purification of the inflowing water before the outlet was reached, and yet even under those excellent conditions it is possible to have introduced unexpected and upsetting factors, as is instanced by the history of the typhoid epidemic at Auburn, N. Y.

Lake Owasco is one of the so-called "finger lakes" of western New York. Its length is about ten miles, breadth one mile; its watershed is about 190 square miles; and its depth is about 175 feet. A small stream enters its head, and Auburn,

a city of some 30,000 inhabitants, has an intake located at the north end or foot of the lake and forty feet below the surface. The temperature of the water at that point in May, 1913, I found to be 42° F.

The peculiar feature of the case which has special interest here is the possibility of polluting material of fecal character being transported from a village near the head of the lake, down the inlet stream, and then northward for the entire ten miles of the lake's length to the Auburn intake situated near the lake outlet.

We have all faithfully held to the dictum that "sedimentation and time" are the great purifying agencies upon which to rely for the natural improvement of a once polluted water; and it takes a good deal of evidence to persuade us that sewage of a small village could make the trip down such a lake in a length of time and in such a manner as to dangerously affect the water of the lower end. Experimental data, however, have been secured showing that such a result can actually take place. Investigation showed the following facts: The village sewage was, of course, small in volume, but during the winter months it was deposited at several points upon the banks of the inlet stream and there it collected in a more or less frozen condition until the occurrence of the spring thaw, at which time there was opportunity for much accumulated fecal material to be washed into the lake in a state of suspension. There was also a chance of its being actually ferried upon cakes of ice, for the reason that certain privies were located upon bridges and fecal matter was dropped upon the very centre of the ice-covered stream.

As stated, the shape of the lake is long and narrow and its axis lies north and south. It must be further noted that the prevailing wind is from the south, with a tendency to blow the surface water directly toward the city intake at the north end.

By means of triangulation and the use of floats constructed so as to be moved by water currents existing at the different depths of from five to twenty feet, it was ascertained that the upper strata of water moved northward with the wind, as would have been expected. The rate of this movement being ascertained, it was found that with relatively light winds the movement of the water down to a depth of five feet amounted to about three per cent. of the wind movement, while at lower

depths this water movement diminished to as low as three-quarters of one per cent. of the wind movement. Thus, to quote from the figures of Mr. Ackerman, who made these tests, with a wind movement of six miles per hour the percentage which the water movement was of the wind movement was as follows: At 5 feet depth, 3.2 per cent.; at 10 feet depth, 1.74 per cent.; at 15 feet depth, 0.87 per cent.; at 20 feet depth, 0.75 per cent.

With a higher wind velocity the water also travelled with greater velocity, but its movement was then not so large a percentage of the wind movement. Thus, with a wind blowing 17 miles an hour the water movement at a depth of five feet amounted to but one and a quarter per cent. of that of the wind. From these data it was easy to calculate that pollution entering the head of the lake could make the trip to the foot of the lake in three days or less.

Knowing, as we do, from Dr. Houston's experiments, that cold water below 50° F. will favor the longevity of the typhoid fever bacillus, it is easy to see how entirely possible it would be for living germs to reach the intake in dangerous condition.

It will be noted how striking is the resemblance which some features of this case bear to the classic instance of the outbreak of typhoid fever at Plymouth, Pa., where the whole trouble came from the dejecta of a single individual being thrown out upon a hillside where it froze and accumulated for weeks and finally, upon the coming of the thaw of spring, was washed into a stream tributary to the city reservoir. This sudden washing of accumulated fecal material furnished in both of these instances a volume of pollution out of all proportion to the amount which would be daily derived from the contributing population during ordinary times of fair weather, and as a result it overtaxed and broke down nature's ordinary means of purification and protection.

There is no question but that this particular case, showing, as it does, the dangers that may arise from such winter accumulation, and showing further the possibility, under favorable conditions, of the transportation of such material over considerable distances in a lake, will cause many of us to materially amend our notions about the dependence to be placed upon lake and reservoir storage as a means of protection against the evils

following water pollution. We should not trust to simple storage without a thorough knowledge of just how it is being accomplished. The writer has in mind an instance of a large lake some five miles in length which has a stream entering within one mile of a city intake, and, because of the entering water having a low specific gravity, there is a possibility of its flowing over the surface of the lake toward the intake whenever the wind is in the right direction. The great length of that lake is, under such circumstances, of small value for purification purposes.

All of this certainly goes to show that we should be cautious about banking too strongly upon the efficiency of reservoir purification under all circumstances, and it demonstrates the necessity of our being well acquainted with the conditions surrounding each individual case before venturing an opinion on the matter.

It should be noted here that, in judging of the bacterial efficiency of lake or reservoir storage, the interpretation of the results of an examination may be obscured by an increase in the total count of bacteria reported due to the disturbing influence of the spring or autumn "turnover."

In conclusion, permit a word to be added concerning the value of storage as a protection against spreading disease through the use of an "emergency" water supply. The underwriters very properly insist upon a sufficient fire service, which shall be available in the event of a temporary breakdown of the regular distribution system. It too often happens that upon such occasions a very inferior water is supplied by the "emergency intake," and as a result of its use there follows an outbreak of typhoid fever. Commonly, some old intake is allowed to remain in place for "emergency service," when pollution of the former supply has so grown in intensity as to force the authorities to seek a new source for public water.

Further fouling of this old supply goes on progressively as population increases, until after some years the water becomes practically dilute sewage. Suddenly some accident to the regular water system induces the authorities to open the old gates, and the result may be imagined.

Such has been the history of typhoid epidemics in a number of cities.

Storage for a sufficient length of time, supplemented, if necessary, by an appropriate dose of bleaching powder, will render even a poor water acceptable for emergency uses, and the reservoir capacity for such storage need not be large.

(There followed lantern slides giving photographs of various forms of microscopic animal and vegetable life, especially those that produce taste or smell in water. Views were also shown of reservoirs before and after stripping; floats used to measure lake currents, and methods for protecting a water-shed against pollution.)

Radio-active Thermo-mineral Waters. G. MASSOL. (*Comptes Rendus*, clv, 373.)—The springs at Usson consist of three groups: (1) three springs at Source Condamy; (2) one spring at Source des Plaies; and (3) two springs at Source Soumain. They all contain about the same quantity of sulphur. The waters from the first two groups evolve on boiling about 16 to 20 c.c. per litre of gas which contains about 1 per cent. of carbon dioxide and hydrogen sulphide, the residue being nitrogen and inert gases. The gases are radio-active, and the calculated activity of the waters is the same for both groups.

Sweden's Hydro-electric Development in 1911. ANON. (*Sci. Amer.*, cvii, 9, 175.)—The hydraulic plants erected in Sweden in 1911 amount to nearly 40,000 horsepower, and if the extensions to existing plants are included, the total will reach 67,667 horsepower, as against 62,385 for the preceding year. These figures refer only to electric power plants installed by private companies. The height of the fall used here is generally made 80 feet, but varies up to 240 feet.

The Electric Furnace and Ferro-silicon. ANON. (*Sci. Amer.*, cvii, 9, 175.)—The electric furnace process is very advantageous for the production of compounds of iron and silicon or ferro-silicon; and even pure silicon can be produced. By the usual blast-furnace methods the best that can be obtained is a product containing a maximum of 20 per cent. silicon, but much richer compounds are obtained by the electric process. Moreover, the impurities, such as calcium, manganese, carbon, etc., are much lower than by the old process. Ferro-silicon containing less than 30 per cent. or over 65 per cent. of silicon is stable, but products between 30 and 65 per cent. are easily decomposed. From the chemical standpoint it is admitted that there are three iron silicides, and perhaps two others. The present process is now being operated in Europe and is covered by patents; the electric furnace somewhat resembles a calcium carbide furnace, but to obtain good results a large-sized furnace is essential. They should also be near to the supply of raw material, and should have good transportation facilities for the finished products.

LIGHT SIGNALS.*

A DISCUSSION OF THE OPTICS, SOURCES OF ILLUMINATION, AND MOST EFFICIENT DISTRIBUTION OF LIGHT FOR RAILWAY SIGNALS GIVING DAY AND NIGHT INDICATIONS.

BY

C. O. HARRINGTON, JR.,

Union Switch and Signal Company, Swissvale, Pa.

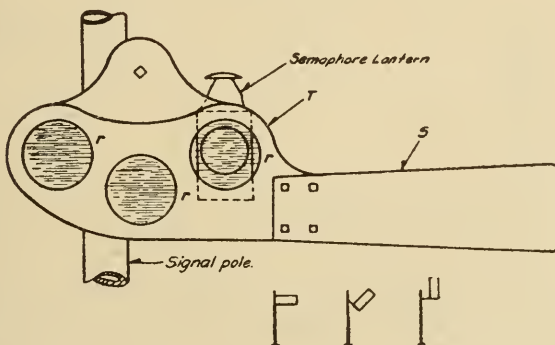
CHAPTER I.

ELEMENTS OF SIGNALLING.

Introductory.

FOR the benefit of those not familiar with modern practice, the author believes it best to outline the purpose of railway signals.

FIG. 1.



To permit the safe handling of traffic, it is necessary to provide a minimum space interval between trains running in the same direction, and, in addition to this, on single-track lines, to control meeting points for trains running in opposite directions. Where tracks cross at grade it is necessary not only to give one train the right to proceed but at the same time provide a means of stopping certain other trains which might attempt to use the crossing at the same time. Starting with a flag and a lantern, many forms of signals have been developed, all being designed to convey orders to the runner, to "signal" him whether he is to stop his train or proceed with safety. Within the limits of this paper there is no space for discussion of the numerous signals which have been used; it is enough to state that present-

* Communicated by the author.

day practice favors the "semaphore" signal, which in its latest "upper quadrant" type is shown in Fig. 1. The semaphore arm is composed of a wooden or metal blade *S* attached to a heavy metal frame *T* known as the "spectacle," which carries three colored glass "roundels," *r, r, r*; behind these roundels there is a lantern, and at night the color of the light is thus determined by the blade's position. The different aspects presented by this semaphore and the "indications" or orders which these aspects convey to the engineer are given in Table I, which also shows the corresponding colors commonly used for night indications. All parts are properly counterweighted to insure the semaphore arm returning by gravity to the "stop" position.

TABLE I.

Aspect Fig. 1.	Position of blade.	Color of light at night.	Indication.
A.....	0°	Red	Stop.
B.....	45°	Yellow	Proceed with caution, expecting to stop at next signal.
C.....	90°	Green	Proceed.

The Block System.

In controlling the spacing of trains in his territory, a dispatcher must maintain telephone or telegraph connection with numerous agents or operators to whom he can transmit orders for stopping trains. His division is subdivided into a number of "blocks," this appellation being given to the distance, perhaps two, perhaps ten miles, between his agents at the block stations. Any agent when so ordered by his chief or for sufficient reasons of his own may display a stop signal and detain a train for orders or until he gives the engineer and conductor permission to proceed.

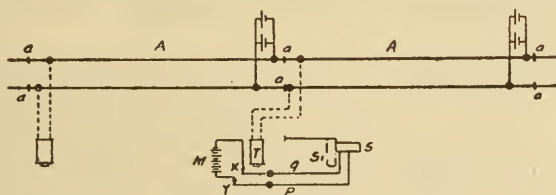
The usual practice in "telegraph block" signalling is to permit but one train at a time to occupy a block, though two or more freight trains may under certain conditions be allowed to occupy the same block under restrictions somewhat limiting speed. As the number of trains increases, the length of the block must be shortened, necessitating additional stations and operators. Both the expense of maintenance and the annoyance of train delays will then increase rapidly. As a result, the "automatic block" system is desirable and is now in extensive use, either as a supplement to the telegraph block or superseding it altogether. While this

does not relieve the dispatcher of his duties in getting trains over the division, it enormously increases the capacity of the line on account of the greatly diminished space interval between trains, and at the same time, as may be seen from the ensuing description, it adds greatly to safety by substituting for the human element an automatic train spacing. Experience has shown the automatic block system to be very dependable, millions of correct signal operations being obtained for every dangerous failure.

Reduced to its elements, the automatic block system consists of a series of track circuits, each of which controls an automatic signal, these circuits being so constituted that when the rails of any track circuit are short-circuited by the wheels and axles of a train the signal which this track governs is allowed to assume the stop position.

The automatic signal is usually a semaphore arm (similar to Fig. 1) whose position is controlled electrically by a battery M ,

FIG. 2.



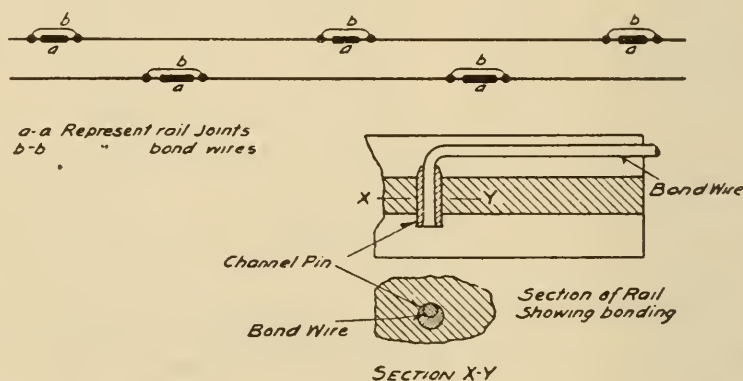
an electric motor, and a system of gears and holding magnets. Referring to Fig. 2, p and q represent the two wires connecting battery M with the electric mechanism operating the semaphore S ; opening the circuit pq de-energizes the magnets holding S in the clear position and allows the semaphore to drop back by its own weight to the stop position S_1 . The position of S may thus be controlled by a relay T , the magnets of which when energized cause contacts xy to close, thus completing the circuit between battery M and signal S .

The track to be signalled is divided into a number of short "blocks" A , usually about 4000 feet long, by insulated rail joints a , and each block A thus constitutes a local circuit. At one end of this block a few cells of battery are connected to the track, and the current from this battery passes through the rails to the 4-ohm relay T at the opposite end of the block and energizes the magnets of this relay so as to close contacts xy . To maintain electric continuity, the rails are "bonded" as illustrated in Fig. 3.

When a train enters section *A*, the wheels and axles constitute a very low resistance "shunt," and relay *T* is de-energized, allowing the signal to return to the stop position, where it will remain so long as the train occupies the block. As the entire division is composed of a succession of block sections *A*, a train is always protected by a stop signal behind it, which forbids a following train entering the occupied block.

Trains are frequently run at such speeds, on such descending grades, and with such brake equipment that it is impossible to stop under 3500 feet; the track alignment or the location of signals is very often such that an unobstructed 3500-foot view cannot be had, and, even when such a range is possible, weather conditions may be such that the signal indication cannot be read at that distance. It is, therefore, deemed necessary to arrange the auto-

FIG. 3.



matic signal circuits so that the presence of a train two blocks in advance may be indicated as a warning to following trains. Many schemes are in use to secure this protection, but space permits only the description of the "three-position" automatic block giving the "proceed," "caution," and "stop" aspects illustrated in Fig. 1.

To understand the protection afforded by this system, refer to Fig. 4. *A*, *B*, *C*, etc., represent the adjacent sections of a continuous automatic block system; *a*, *b*, *c*, etc., are the signals governed by these sections; the position of every signal is governed, first, by the track relay of its section (see Fig. 2), and, second, by the position of the signal in advance; thus while there is no train in block *E*, the signal *e* is standing at caution, indicating that the block *D* is occupied and warning the engineer

to reduce speed. The most dangerous condition occurs when a train *X* has stopped immediately after entering block *B*; but the reader will note that the following train *Y* is warned by signal *c* in the caution position that he must be prepared to stop at *b*. The necessity for such protection has been emphasized in practice. For example, in the situation shown in Fig. 5, where no caution signal has been provided and train *O* has stopped just inside block *M*, a following train *P* would get a proceed signal *n*, and would not slacken speed. The severity of a collision would be aggravated if stop signal *m* were visible only a short distance.

Range.

Analysis of the signalling system in Fig. 4 will show the reader that the range of a signal—the distance from which an

FIG. 4.

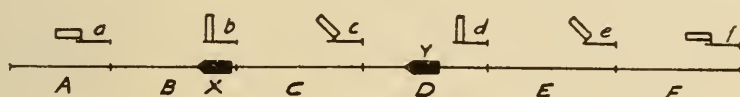
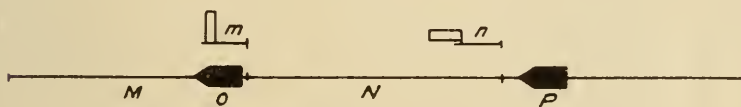


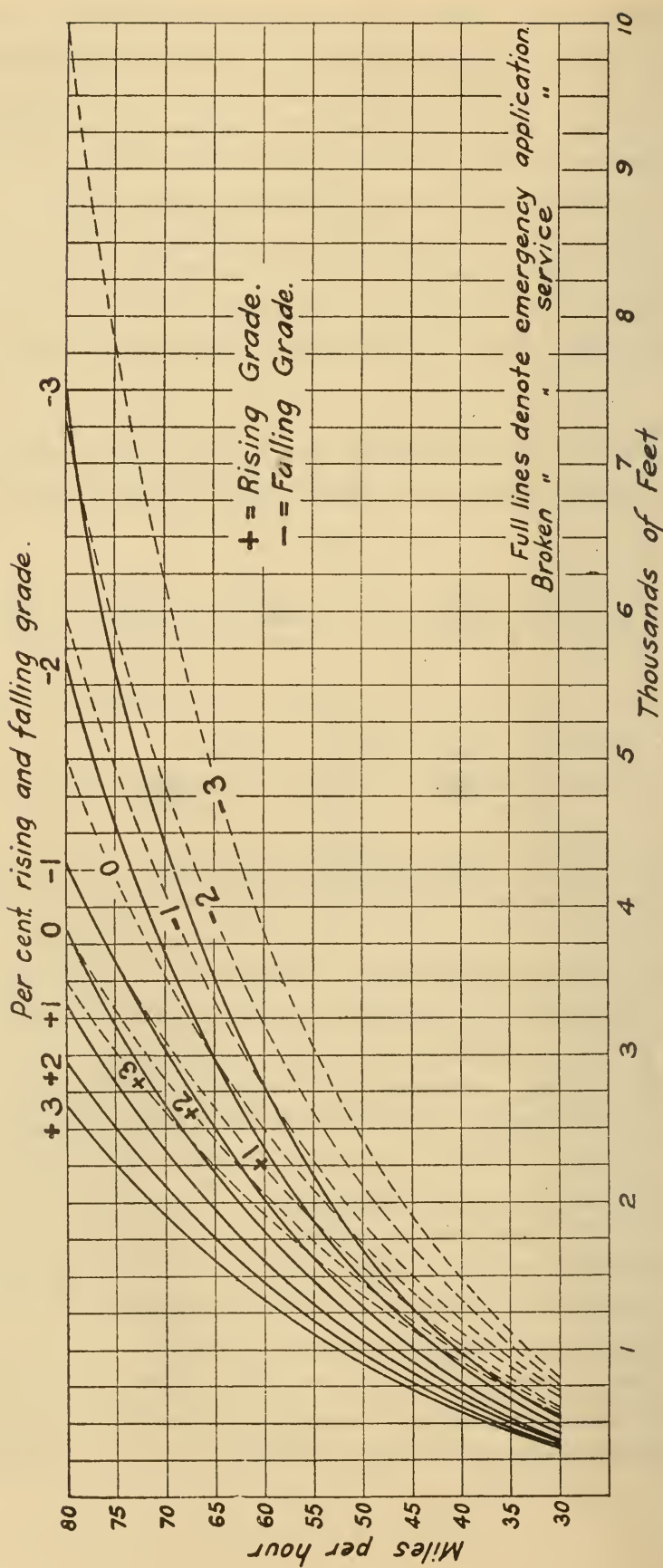
FIG. 5.



indication can be clearly recognized under most unfavorable conditions—together with the maximum distance required to brake trains to a standstill, jointly influence the speed at which trains can be safely operated. Before fixing the signal range, which is to some extent variable and determined by the design of the signal, due consideration must be given to the factors of speed and braking, which cannot be varied without great inconvenience and expense. Speed is limited by the topography of the country which a railroad traverses and by the maintenance and quality of roadway and equipment. The condition of the air brakes is by far the most important factor influencing speed, but, as the effect of brakes is itself varied by grades, it is necessary to present a series of curves for different grades if any accurate idea of brake performance is to be obtained.

It is with some hesitation that the author ventures a discussion of braking distances, realizing that many factors must be taken into account, and that, therefore, any comprehensive or

FIG. 6.



Distance required to brake trains.

universal statements are impossible. Moreover, as improvements in brake design are keeping pace with those in other progressive branches of engineering, all present data may soon become obsolete. The curves, Fig. 6, are submitted merely as an indication of what will be obtained under the assumed set of conditions which are believed to be typical of brake equipment and maintenance commonly found to exist on passenger trains. We may consider these curves typical of the distances required to make "full service" and "emergency" stops with good average brakes of the ordinary "high-speed" type and 110 pounds brake-pipe pressure. Engines running light may sometimes exceed these braking distances, as they are not braked up to their full wheel load.

Empty freight cars can be braked readily enough, but a train of loaded cars is harder to handle, as it is not yet customary to increase the brake-shoe pressure on loaded cars over that on empties; as a result, a loaded freight train is usually only braked to about 20 per cent. of its wheel load. Unless the speed is carefully regulated, especially on falling grades, such a train will require a very great distance to brake to a standstill. One cannot, therefore, predict any definite maximum braking distance for freight trains. It is safe to assume, however, that common practice limits the speed and load of freight trains to a point where they can be stopped in 3000 to 4000 feet. Where conditions exist where it is impracticable or undesirable to keep within this limit, it is necessary to provide longer blocks or else to use some overlap protection as illustrated in Fig. 63.

The intersections of the vertical lines with the curves of Fig. 6 indicate the speed in miles per hour permissible if a train is to be stopped by signals whose ranges are denoted by these vertical lines. Unless means be provided to give advance warning of its position, average conditions will seldom allow a signal to be recognized at sufficient distance to insure bringing a fast train to a stop without overrunning the block, and the caution indication as described in Fig. 4 was accordingly designed to prevent trains coming upon stop signals without advance warning to reduce speed. Every precaution is taken to prevent a train from a siding taking the main line after an approaching main line train has passed the second signal in the rear. It may be said that on a well-signalled road only deliberate violation of the book of rules by a train crew, or an accident to rolling stock or structure,

can cause a stop signal to be presented in the face of a train authorized by the last signal to "proceed at full speed." Therefore, arguments for long-range indications as a means to prevent overrunning a "stop" signal, though certainly worthy of attention, concern a theoretical factor of safety and cannot be said to have a direct bearing on the normal operation of trains. There remains, however, this very practical consideration: trains are frequently passing "caution" signals directing the engineer to bring his train under control so that he can stop if necessary at the next signal. It is not always possible or customary to locate caution signals as far behind home signals as would be necessary to insure all trains being stopped without overrunning the home signal if the runner does not apply brakes before passing the caution signal. For this reason, it is an advantage to have a distant signal which can be seen 1500 to 2000 feet, as the long range of this signal will have a similar effect to a signal of shorter range set farther back of the home signal. Reference to Fig. 6 will show that a signal having 2000 feet range can be seen far enough to brake an express train from 54 miles an hour to a standstill on level track without overrunning the block if the runner makes a "full service" application when he first sees the signal. It is obvious that with such signals both the safety and convenience of train operation is increased, especially where caution signals are located but a short distance from the home signals which govern them. Moreover, the increased range results in the runner being able to avoid excessive braking and still obey signals.

Those interested in a more complete description of block signalling are referred to Mr. J. B. Latimer's book, "Railway Signalling in Theory and Practice" (Mackenzie-Klink Publishing Company, Chicago).

CHAPTER II.

THE LIGHT SIGNAL.

Having considered the elements of signalling, we can now intelligently study the factors involved in the design of light signals.

The ordinary semaphore lantern used for night indication is, strictly speaking, a light signal; it projects a beam of approximately 60 candle-power, which, while sufficient for a range of one

to three miles at night depending upon atmospheric conditions, is not designed for daylight indications. Throughout this article we shall use the term *light signal* in its customary significance as referring to signals projecting sufficient candle-power to afford satisfactory indications in daylight, as well as night.

Small light signals having a daylight range of 100 feet or more have been used for years on trolley roads, principally to hold cars on passing sidings; they have also been used in tunnels and at stations, and locations where the subdued light is favorable for displaying a signal of low candle-power. The first extensive application of light signals to railroad service was the installation on the Pennsylvania Tunnel and Terminal Company in 1910. These signals were designed by the Union Switch & Signal Company and were of the form shown in Fig. 7, the indications being given by one 40 watt and one 20 watt Tungsten lamp behind each lens, the lenses being colored as indicated in Fig. 7. In these signals it was not necessary to secure a range of more than 500 feet, consequently small lenses with large lamps behind them so arranged as to give considerable spread to the projected light were found satisfactory.

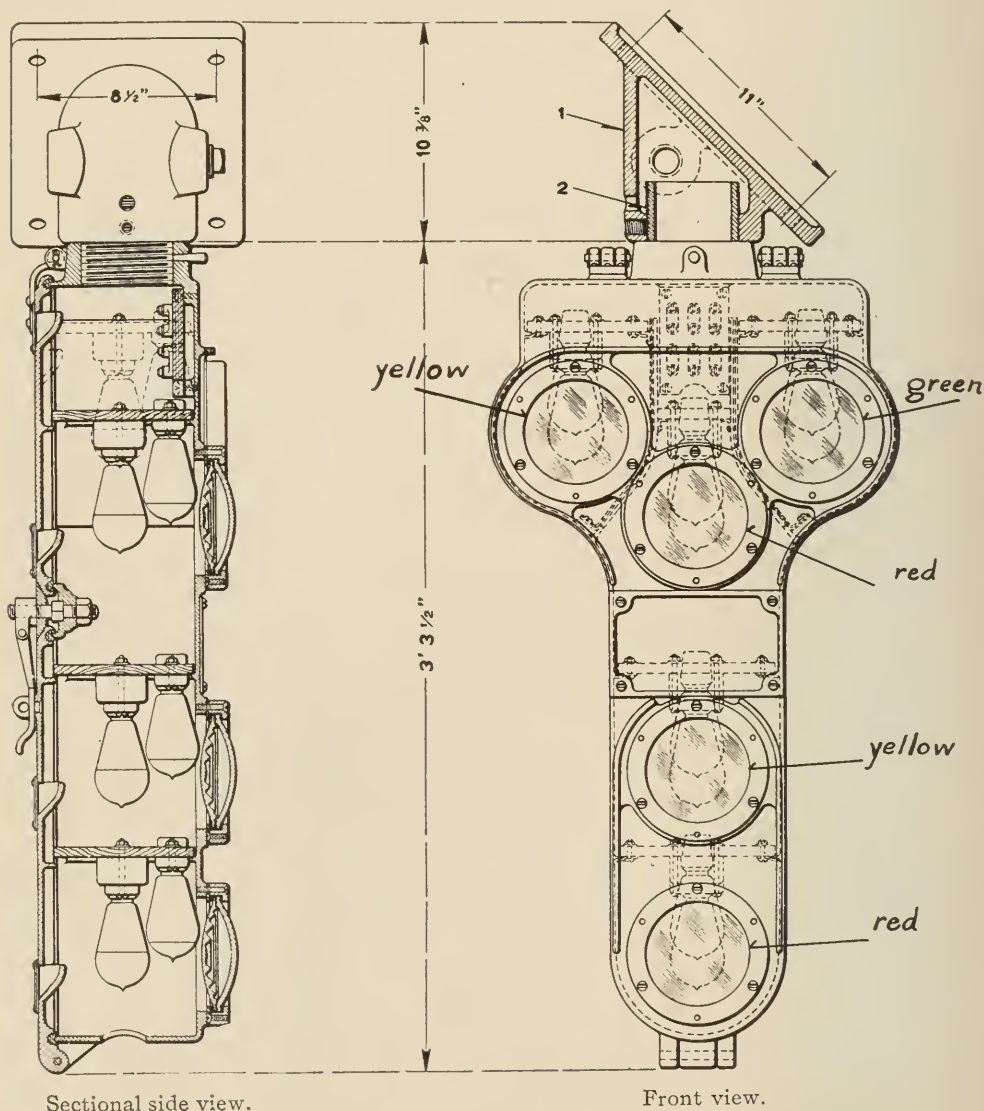
In these initial light signal installations color only was employed to give an indication and this practice has been maintained throughout the developments of the last four years. During this time light signals have been employed to some extent, both for interlocking and automatic block signalling on interurban lines.

It has been found advisable, however, to constantly increase the range of light signals, and as a result the design has been altered from Fig. 7 to Fig. 8, which illustrates a construction now in service. The colored lenses *G*, *Y*, *R* are placed close together to economize space, and in order to make the lights clearly visible in sunshine at ranges of 1000 feet or more it has proved necessary to surround the lenses with a large background *A* and enclose them in a hood *B*, both *A* and *B* being preferably painted black. With this arrangement uncolored glass would project a candle-power of about 400, and the color densities used in the signal are such that it may be seen 1000 feet or more under reasonable conditions.

As electricity was usually cheap and convenient in these light signal installations, it has been customary to burn behind the lenses (Figs. 7 and 8) 25-watt or 40-watt lamps, of which Fig.

17 is an example. This arrangement is not economical and the increasing need for longer ranges at low power consumption has determined a marked increase in the efficiency of light signals which we will further describe under the headings of "Lamps"

FIG. 7.



Sectional side view.

Front view.

Suspended five-light electric light automatic signal. For daylight indications.

and "Lenses." The reader may at this point be interested in noting the curves in Fig. 24, which illustrate how, by reducing the size of the filament, we have been able to increase the intensity of the projected beam from 400 to 6000 or 7000 candle-power. This efficiency is further augmented by selecting the

proper lenses, this being discussed on another page of this paper. To anticipate, we may here state that the candle-power of a light signal has been made fifteen or twenty times greater at the same

FIG. 8A.

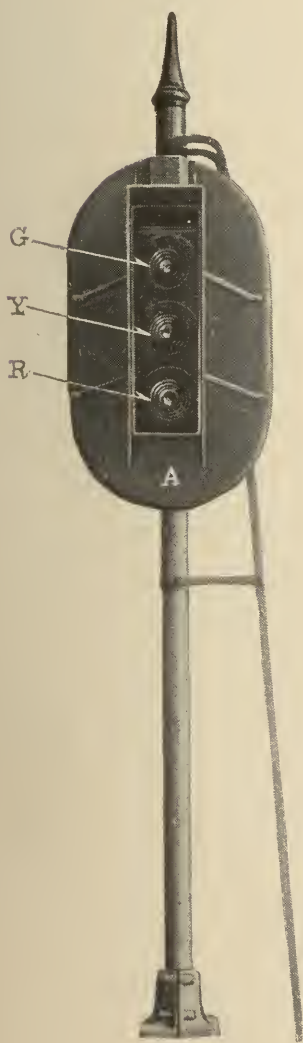


FIG. 8.

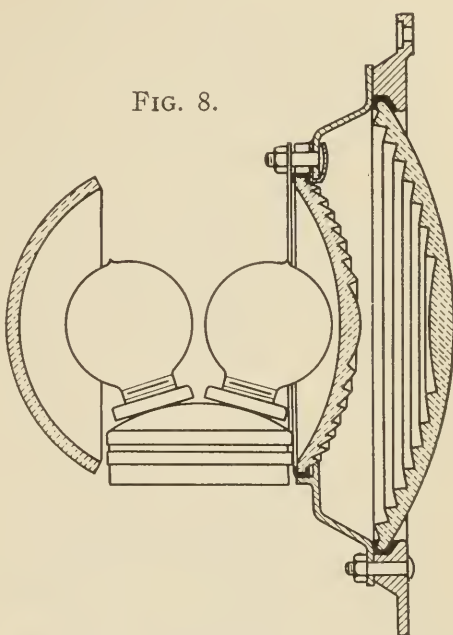
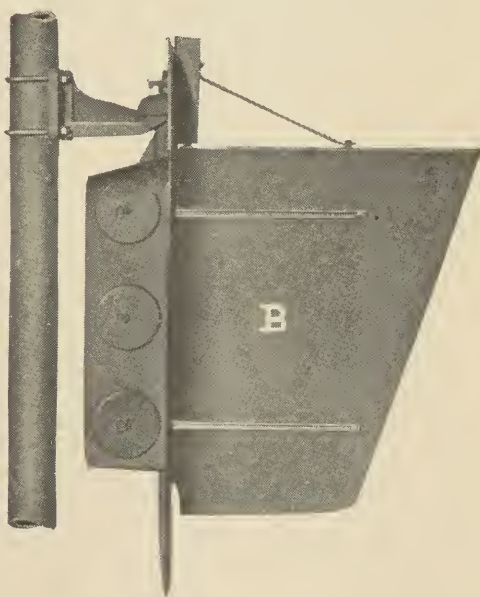


FIG. 8B.

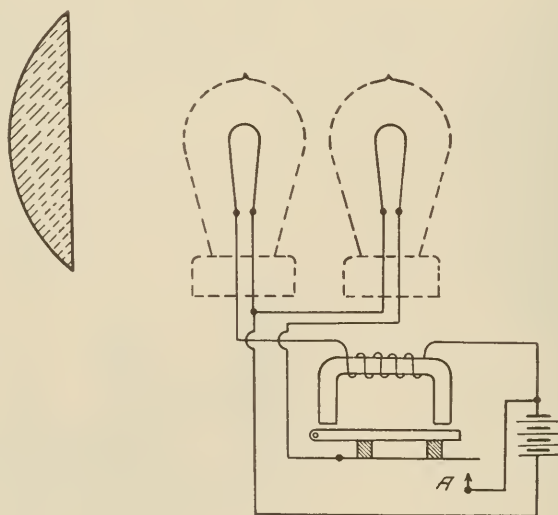


time that an actual reduction in power consumption has been secured, all this being accomplished by employing lamps and lenses of the highest possible efficiency.

In the construction shown in Fig. 8, two lamps have been

mounted behind each lens, the front lamp being in focus and projecting about 90 per cent. of the total beam candle-power, the rear lamp being burned as a safeguard in case the front lamp is burned out. A combination lens is used having an especially wide angle and a very short focus and thus collecting a large percentage of total spherical candle-power of the front lamp. On account of the short focal length of this combination lens, the rear lamp is far out of focus, and a reflector has therefore been provided to superimpose the image of the rear filament upon the front filament, as otherwise the lens would be very slightly illuminated by the rear lamp. To decrease power consumption and increase the life of lamps, it is possible to utilize the well-known device of a

FIG. 9.



relay (Fig. 9) connected in series with the front lamp. In this case the rear lamp is held in reserve and lit only when the front lamp burns out, closing the back contact of the relay and completing the circuit of the rear lamp shown.

Light signals are being installed in increasing numbers, at present chiefly on electrified roads and interurban lines. These signals are safe and easily maintained; they occupy small space, and they may be readily recognized in congested territory or where the right of way is obstructed. Their current consumption is too high to permit economical operation from batteries, except where very low candle-power is required or where signals are displayed only for short intervals of time. Where power is available, either alternating or direct current, light signals may be

operated cheaply, require minimum attention, and provide a very high factor of safety. Suitable power is now becoming abundant, for in recent years alternating current has been supplanting batteries for the operation of automatic block signals. Its use makes possible the elimination of failures due to foreign direct current in the track circuit and also effects increased economy in maintenance.

It would require too much space to discuss the advantages of alternating current signalling; if interested, the reader is referred to a series of articles on this subject by Mr. Harold McCready, appearing in the *Signal Engineer* between May, 1913, and this date, and to the historical reviews of alternating current signalling published in the annual proceedings of the Railway Signal Association for the past four years.

If the light signal is to be adapted to the needs of modern signalling it must be sufficiently prominent to control fast trains, and at the same time its current consumption must be reduced to a minimum, for, even though power be reasonably cheap, the current taken by the light signal lamps, 24 hours a day, will represent a large percentage of the total operating cost of a signal system employing light signals. It is also desirable to keep down the first cost of a signal installation by reducing the power taken by each signal unit, as this frequently permits economy of copper in that very expensive element, the power transmission line.

The design of a light signal, therefore, aims at securing the greatest range with the least lamp wattage, and the remainder of this paper analyzes those conditions and theories upon which correct design must be based.

CHAPTER III.

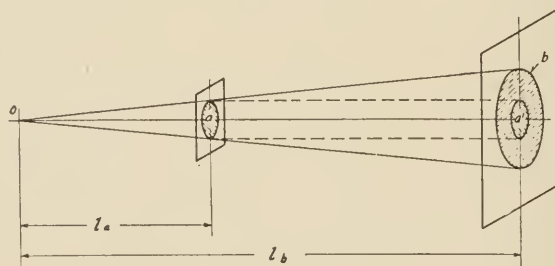
THE INCANDESCENT LAMP AND ITS INFLUENCE ON LIGHT SIGNAL DESIGN.

If increase in the efficiency of light signals is to be secured, there are two factors which assume primary importance. The projector, as we may call the lens or reflector, must be designed to utilize the greatest possible percentage of the lamp's total spherical candle-power, and to distribute this light in the most efficient and satisfactory manner. The source of light must be of such size and so located as to permit the greatest possible pro-

portion of its total spherical candle-power to be projected in useful light. The source of light—in our case the lamp filament—will be considered first as having the most marked influence on efficiency, but, before anything further is said, we must understand two principles underlying the design of a signal or reflector.

Neglecting several factors which influence the range of a signal light, the “visibility” of a light—the effect which it produces on the observer’s eye—is proportional to the candle-foot illumination at the observer’s station. One candle-foot is an illumination equal to that thrown by a one candle-power light on a surface one foot away. Obviously, if you take a naked light, the candle-foot illumination at any point is equal to the candle-power of the light divided by the square of the distance in feet between that point and the light, for, referring to Fig. 10, the

FIG. 10.



same amount of light that falls on a surface a distant l_a from the source of illumination O will be distributed over a larger surface b if the distance is increased to l_b , and $\frac{b}{a} = \frac{l_b^2}{l_a^2}$; therefore the amount of light falling on a surface $a' = a$, distant l_b from O , will be $\frac{a'}{b}$ or $\frac{l_a^2}{l_b^2}$ of the light received by surface a . It will thus be seen that the illumination afforded by a light diminishes very rapidly as the distance increases.

Figs. 11 and 12 show respectively a lens and a parabolic reflector, both concentrating that portion of the total spherical candle-power included in the shaded cones bounded by the lines AoB and $A'oB'$. The effect of this concentration is to increase the *useful* candle-power by avoiding dispersion of light where it is not needed. It might be thought that by combining a perfect projector with a point source of light, and so focusing it as to project a parallel “tube” of light, this law of inverse squares

would no longer hold and the candle-foot illumination would be the same at all distances; as a matter of fact, no commercial lens or reflector can be built without giving some spread, and it is likewise impossible to secure a point source of light, consequently the light from any lens or reflector will always be projected as a cone having greater or less spread, depending upon the construction and also upon the area of the source of light, and the

FIG. 11.

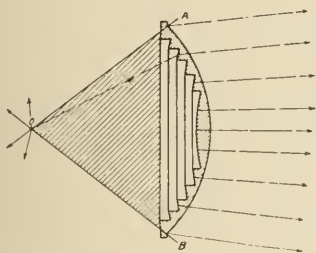
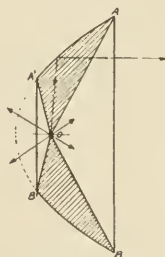


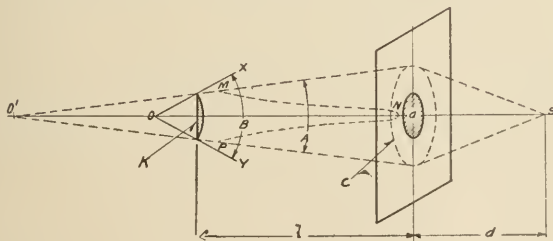
FIG. 12.



law of inverse squares may be said to apply universally. The amount of spread has no effect on the law of inverse squares, but it changes the candle-power decidedly; referring to Fig. 13, lens K collects all the light from source O included in the cone XOY

having angle B , and projects this light, which is $\frac{1 - \cos \frac{B}{2}}{2}$ of the total spherical candle-power in a cone of much smaller angle A .

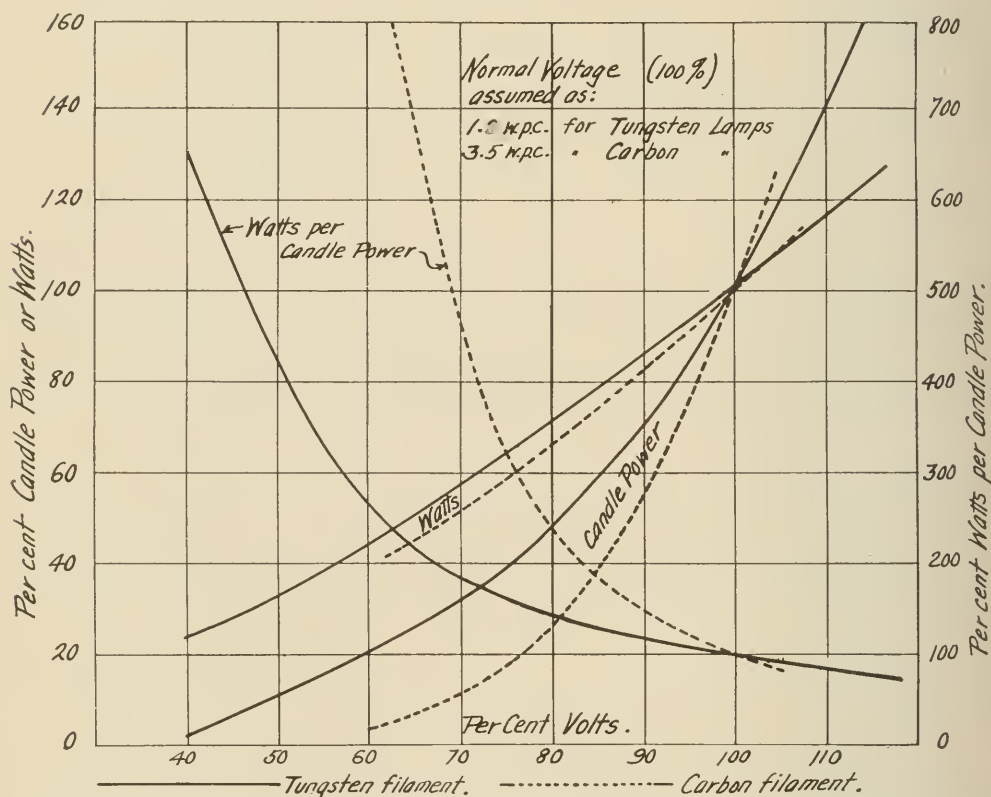
FIG. 13.



Now the candle-power of the projected beam A is photometered by moving a light of known candle-power S into such a position that the illumination thrown by this standard lamp on a small photometer screen having area a is equal to the illumination received from lens K . The candle-power of K is then determined simply by the law of inverse squares, viz., $Kcp = \frac{l^2}{d^2} Scp$. Obviously, the greater the angle A the greater the area C over

which the light from K is spread and the smaller the percentage of the total light XOY received by the photometer screen a , whose area remains unchanged. Were the candle-power the same throughout angle A , we could say that the candle-power of a lens varied inversely as the square of its spread; but the candle-power at different angles throughout A varies somewhat as shown by curve MNP , where the distances from O' to this curve represent

FIG. 14.



Variation in candle-power, watts and watts per candle-power caused by variation in voltage at which lamp is burned.

candle-power. Thus we cannot make any general statement, except that the candle-power of a lens or reflector decreases rapidly with the spread of the projected rays; the exact decrease can only be given for specific cases.

Lamps.

Only tungsten lamps will be considered as a source of illumination, as they are more economical and satisfactory than carbon lamps; a carbon lamp of the small candle-power desired will

require 3 to 4 watts per candle-power, while tungsten lamps of the same size will require only 1.25 to 1.5 watts per candle-power. Furthermore, the light from the tungsten filament, even when burned under voltage, conforms more nearly to that of sunlight than does the carbon filament lamp, the shorter wave-lengths of the tungsten lamp between the *D* and *H* lines of the spectrum being more powerful (see Fig. 69) ; moreover, the reduction in its candle-power, due to lowered voltage, is less than that of the carbon lamp, as can be seen by inspection of the typical voltage = candle-power curves for tungsten and carbon filaments shown on Fig. 14.

FIG. 15.

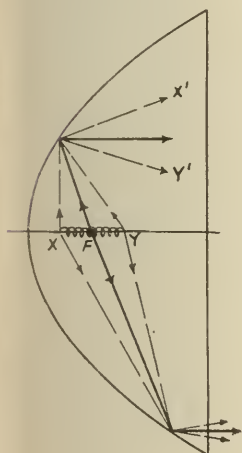


FIG. 16A.

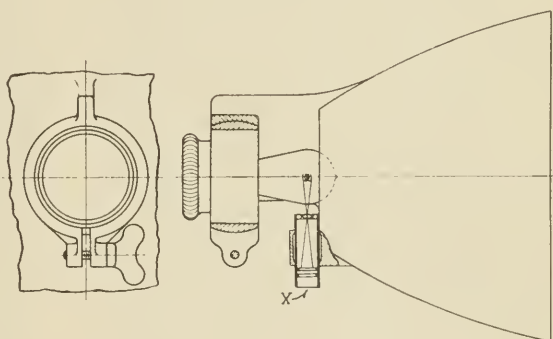


FIG. 16B.

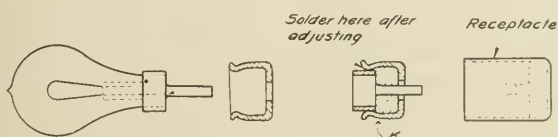
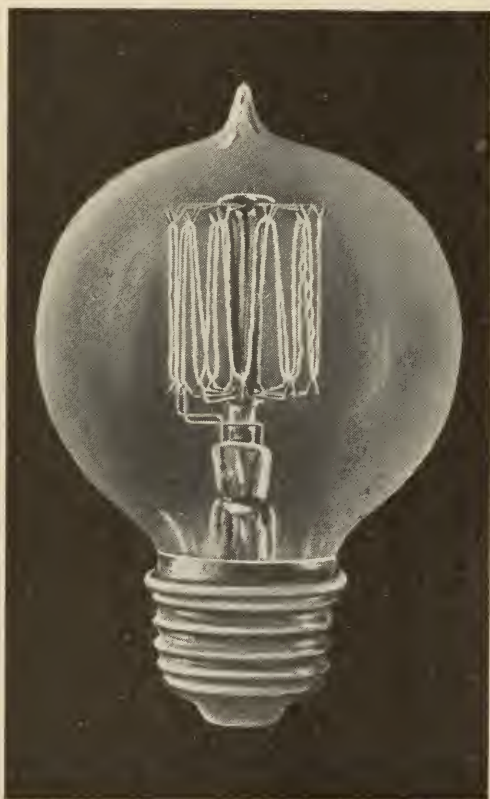


Fig. 16A shows a sight for locating a lamp filament correctly at focus of signal. Fig. 16B shows an adjustable base which can be aligned correctly with lamp filament and thus correct for variations in the manufacture of lamps.

If efficiency be measured by the watts energy required to project a certain candle-power from a lens or reflector, it is obvious that the greatest efficiency can be secured by concentrating the light in the smallest possible space as close as possible to the focus of the lens or reflector. Referring to Fig. 15, you will note that all that portion of the filament *xy* lying outside the focus *F* of the parabola projects diverging rays, and that only that portion of the filament located at *F* is really efficient in projecting candle-power ; the same is true of a lens. For manufacturing reasons it is not practicable to concentrate all the light at a point, and it is not desirable to reduce the spread of the

projected beam too much. As the source of illumination approaches a point, a very small shifting of the lamp globe will throw the incandescent filament out of the focus; in the manufacture of incandescent lamps and lamp parts $\frac{1}{16}$ inch to $\frac{1}{8}$ inch variation in the location of the filament is to be expected. If a very small filament is used it is advisable to provide an adjustable lamp socket *A*, Fig. 16, so that when renewing a lamp the

FIG. 17.



110-volt, 25-watt.

FIG. 18.



110-volt, 25-watt.

maintainer can readjust the socket to bring the filament right at the focus, using a finder *X* to determine the correct location of filament; or the base *K* of every lamp may be located in exactly the correct relation to the filament, as shown in *B*, Fig. 16, so that all lamps will be interchangeable without any readjustment of the signal. Unless this is done, the size of the filament must be increased to compensate for variations in its location. We can secure a certain candle-power and spread of light with a 20-watt concentrated filament accurately located at the focus of the signal

FIG. 19.



55-volt, 15-watt.

FIG. 20.



12-volt, 10-watt.

FIG. 21.



12-volt, 10-watt.

FIG. 22.



6-volt, 5-watt.

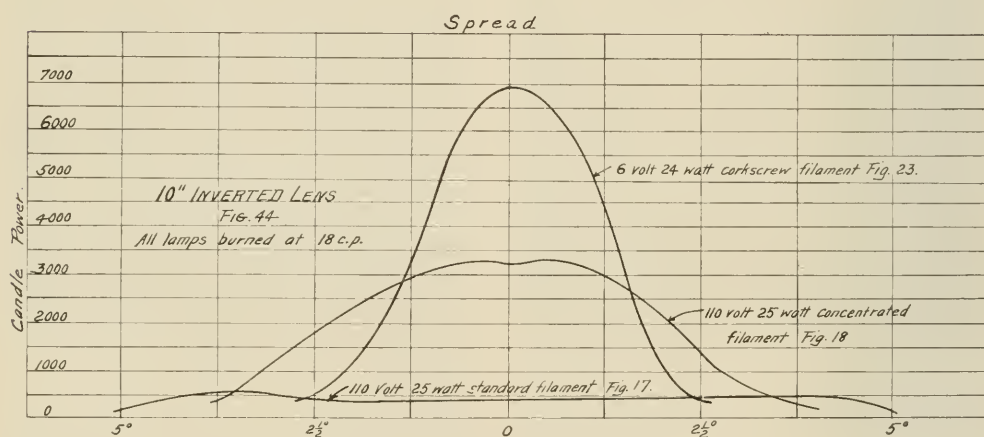
FIG. 23.



6-volt, 15-watt.

lens or reflector. If we attempt to use lamps having a $\frac{1}{16}$ inch variation in position of filament and expect to renew these lamps without any adjustment, we must increase the lamp watts to about 50 to compensate for variations and prevent the spread or the candle-power of the signal from being seriously affected by a change of lamps. Similarly, $\frac{1}{8}$ inch variation in the location of lamp filament would require an increase to 110 watts to compensate. Undoubtedly the best results can be secured, and at the least expense, by accurately locating the filament with respect to the base, as otherwise the maintainer will have to re-align the lamp receptacle every time he renews a lamp.

FIG. 24.



Comparison of different lamps behind the same lens.

Within the past year manufacturers have done much to develop a concentrated filament lamp by winding the tungsten filament in a fine helical coil and looping this coil over the filament supports. As an example of the extent to which the light has been concentrated, the author submits photographs of seven tungsten lamps (Figs. 17 to 23 inclusive); Fig. 23 is a "corkscrew" filament automobile headlight lamp, which has been in use for several years in parabolic electric headlights. In this connection it is interesting to note the comparative distribution of light from the inverted lens illustrated in Fig. 44 with different types of filament, and the curves in Fig. 24 have been plotted to show the candle-power at different angles from the optical axis of lens.

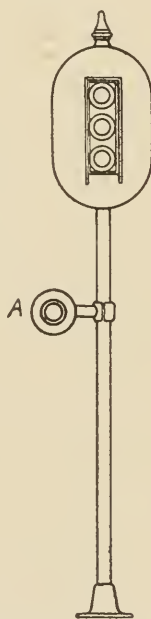
As mentioned earlier in this paper, an enormous increase in candle-power has been obtained, even where the power consump-

tion has actually been decreased, by concentrating the illumination at the focus of the lens, instead of permitting a large spread of illuminated filament similar to Fig. 17 where a considerable percentage of the filament has little value for projecting light.

The use of two lamps in multiple as shown in Fig. 8 is somewhat uneconomical. The rear lamp is out of focus, and, even when provided with a reflector, can only give about 10 per cent. of the total beam candle-power; the rear lamp has been provided principally as a safety factor to furnish light in case the front lamp burns out. Of course, a "cut in" relay (Fig. 9) may be provided, to insure one fresh lamp being held in reserve and thus avoid all possibility of both lamps burning out at nearly the same time. The logical solution is to use only one lamp in each signal and renew all lamps at intervals, based on a careful observation of their life. By keeping an extensive record of lamp performance it is possible to forecast the life of lamps with considerable accuracy, and it is thought that lamp failures may, under this system, be reduced much below the percentage of failures now experienced with oil-burning lanterns. The few lamps which burn out before the date set for renewal will entail small delay, and can be reported by the engineers discovering them. A signal which fails to give any indication will always be interpreted as "Stop," and a burned-out lamp is, therefore, not a source of danger *where the signal pole or case can be seen*. In the daytime the background of a light signal is distinct, and there is no danger of an engineer passing a signal if the light is out. As the case and hood are painted black and are, therefore, inconspicuous at night, there is then nothing but the light to inform an engineer that he is approaching a signal, so that if this light were out he might pass the signal without knowing it. Moreover, the light signal is usually controlled by a relay or by a circuit controller of some sort as illustrated in Fig. 48, and to present a correct stop signal indication we must close a circuit and cause a lamp to burn—a principle entirely at variance with the best practice in signalling, which requires that a signal indicate *stop* whenever the circuit *fails* to close, so that a broken wire or imperfect contact cannot prevent the display of a red light. For this reason the author wishes to emphasize the advantages of using with a light signal an independent marker light *A*, Fig. 25, which shall be burning all the time, independently of the signal

indications. This marker may be an illuminated number plate or a lens, but it must not display any color which can be mistaken for a proceed or caution indication; as it is only necessary at night, it may, if desired, be of far lower candle-power than the signal indications; it must be located several feet from the powerful signal lights, in order that its indication be distinct at a distance of 800 or 1000 feet at night, and enginemen should be instructed that a combination of marker and signal is necessary for a correct night indication. Where a single signal is used we must depend upon the marker light for the final element of safety when

FIG. 25.

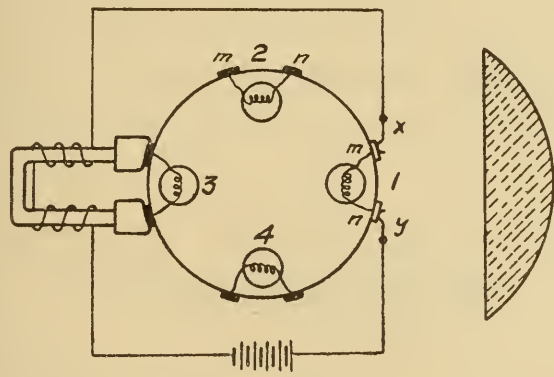


A is a marker light attached to a light signal.

the signal light is out at night, and no pains should be spared to make this marker light as reliable as possible. Assuming that signal lamps are used having a renewal period of three months, the marker lamps might be made of more rugged construction or burned at lower voltage, so that their average minimum life would be six months. Then by renewing the marker lamps at the same time as the signal lamps—once every three months—an increased factor of safety would be gained. In addition to this, there should be two lamps behind the marker light, one of these lamps always being held in reserve to be used in case the first lamp burns out. The second lamp may be cut in through the back contact of a relay, as illustrated in Fig. 9, or several lamps

may be mounted on a revolving base of magnetic material (see Fig. 26), which is operated by a coiled spring not shown in the figure, and held from moving by an electromagnet. In Fig. 26, lamp 1 is at the focus of lens, and the revolving base is held there by an electromagnet which is energized by the current passing through contacts x, m, n, y and the filament of lamp 1;

FIG. 26.



when this filament burns out, the electromagnet is de-energized and the base is caused to revolve by the spring until lamp 2 comes into focus and is lighted, the current through filament of lamp 2 again energizing the electromagnet and preventing further rotation of the base. A safety brake, not shown in the figure, is

FIG. 27.

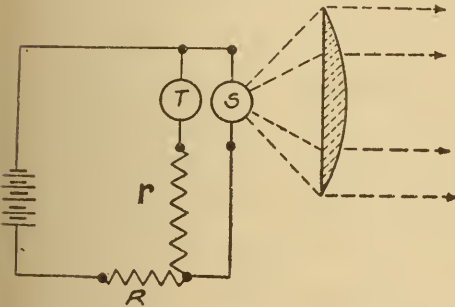
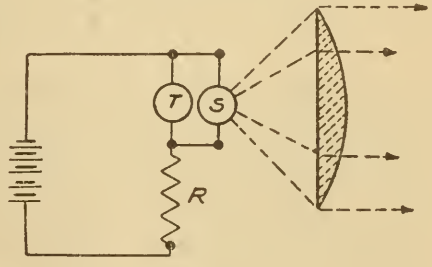


FIG. 28.



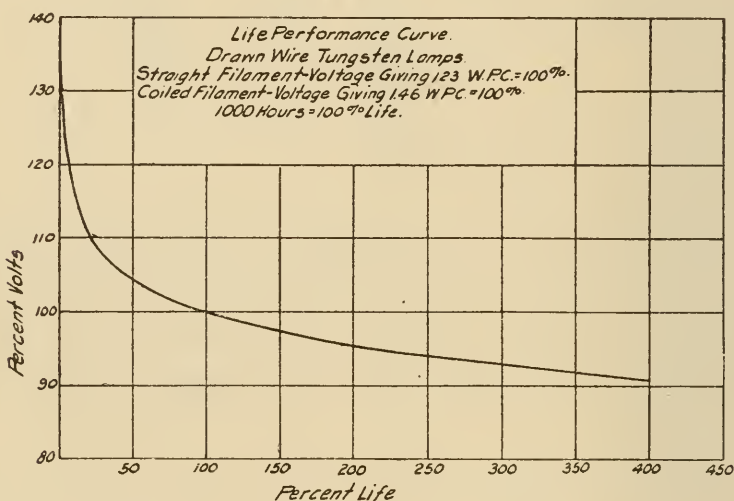
provided to clamp the base and prevent its revolving if the power is cut off the line.

The same result may be secured without using contacts, springs, or magnets, by arranging suitable resistances R and r , according to Fig. 27, so that when both lamp filaments S and T are intact S gets sufficient current to illuminate the lens and T is kept hot but not incandescent, but when S burns out enough

current will be forced through T to "light" this lamp. The filament of T is always hot; it has been claimed that a hot filament is less likely to be broken by vibration than is a cold filament.

Fig. 28 shows a variation of Fig. 27, the lamps being of different voltages, T being the higher voltage lamp. Thus when both filaments are intact the lower resistance of the two lamps in multiple causes greater drop in potential through resistance R , so that S burns but T does not reach the incandescent point. It is scarcely necessary to add that in either Fig. 27 or Fig. 28 lamp S must ordinarily burn under normal voltage, so that the breaking of filament T will not overload S and cause it to burn out.

FIG. 29.



Where long and comparatively uniform life is important, lamps should be burned under normal voltage. Laboratory and service tests favor about 90 per cent. of rated voltage for the class of tungsten lamps used in signal lights; this will be easily understood by examining the curve Fig. 29 and noting the remarkable effect of voltage on the life of certain signal lamps. The author does not intend this curve or the figures preceding to be taken as characteristic of all lamps; they are submitted as illustrating the undoubted necessity for reducing lamp voltage to secure increased life. The efficiency of the lamps is certainly decreased as the voltage is lowered (see Fig. 14). To arrive at any intelligent decision, each case must be handled on its merits, balancing the increased watts per candle-power against the decrease in expense of maintenance and lamp renewals.

(To be continued.)

ELECTROMAGNETIC RADIATION.*

BY

LOUIS COHEN,

Washington, D. C.

THE Hertzian theory for the distribution of the electromagnetic forces and the radiation from a cylindrical oscillator finds an extensive application to problems in radio communication. The formulæ established by Hertz are applicable to antennæ, and are, therefore, used considerably by radio engineers in the study of the transmission of radio signals. The analysis, however, employed by Hertz in the derivation of the formulæ is beyond the mathematical equipment of the average radio engineer, and for some engineers it is altogether an impossible task to follow the various mathematical transformations required in the establishment of the final formulæ, and are, therefore, to that extent accepted on faith, without knowing the limitations and assumptions involved in the work.

It is the purpose of this paper to give a new method for deriving these formulæ in which only elementary mathematics is employed, and thus bring the discussion of the subject within the reach of the average engineer. It is also hoped that it will be of some interest to the experimental physicist who is interested in the subject of electrical oscillations.

Let us consider the case of a straight cylindrical conductor through which an alternating current $I \sin \omega t$ is passing, where $\omega = 2\pi \times \text{frequency}$. The magnetic field surrounding the conductor does not reach out to infinity instantaneously, on account of the finite velocity of propagation of the electric and magnetic forces, hence the magnetic force at any point distance r from the axis of the cylinder lags behind the current by a time interval δt , and we therefore have

$$H = \frac{2I}{r} \sin \omega (t - \delta t) \dots\dots\dots (1)$$

If we denote by u the velocity of propagation, and by r the radial distance to any point, we have

$$\delta t = \frac{r}{u} \dots\dots\dots (2)$$

* Communicated by the author.

Substituting the value of δt from (2) into (1), we get

$$\begin{aligned} H &= \frac{2I}{r} \sin \omega \left(t - \frac{r}{u} \right), \\ &= \frac{2I}{r} \sin \frac{\omega}{u} (ut - r) \dots \dots \dots (3) \end{aligned}$$

In all wave motion we have the relation

$$u = f\lambda = \frac{\omega\lambda}{2\pi}, \dots \dots \dots (4)$$

where f is the frequency and λ is the wave-length, hence equation (3) may take the following form:

$$H = \frac{2I}{r} \sin \frac{2\pi}{\lambda} (ut - r) \dots \dots \dots (5)$$

In the case of oscillatory currents, however, another element must be taken into consideration; namely, the radiation phenomena. Suppose we have the positive half of the wave of the current passing through the conductor setting up a positive magnetic field around the conductor; when the current reaches the zero point, the magnetic field is not reduced to zero simultaneously, since it requires a finite time for the magnetic field to travel back to the conductor. As a consequence, before all the positive magnetic lines of force collapse back on the conductor, a negative magnetic field is set up by the negative half of the wave of the current which repels the positive magnetic field and thus introduces the phenomena of radiation: that is, at some distance from the conductor the magnetic field is not stationary, but is continuously travelling away from the conductor into infinite space.

If we consider any spherical layer at some distance r from the axis of the oscillator, the magnetic flux within it is the difference between the number of lines of force which enter at the inner surface and leave at the outer surface.

Let r denote the inner radius of the spherical layer.

Let δr denote the thickness of the spherical layer.

Let B denote magnetic flux at inner surface.

We have for the magnetic flux at outer surface of the spherical layer $B - \frac{\partial B}{\partial r} \delta r$, and the total magnetic flux within the spherical layer is

$$B - (B - \frac{\partial B}{\partial r} \delta r) = \frac{\partial B}{\partial r} \delta r, \dots \dots \dots (6)$$

and the intensity of the magnetic force within the spherical layer is, therefore,

$$H' = \frac{\partial B}{\partial r} = \frac{\partial H}{\partial r} \dots\dots\dots (7)$$

Substituting the value of H from (5) into (7), we get

$$H' = \frac{2I}{r} \frac{2\pi}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) + \frac{2I}{r^2} \sin \frac{2\pi}{\lambda} (ut - r) \dots\dots\dots (8)$$

For considerable distances from the axis we may neglect the second term of the right-hand side of the above equation as being small in comparison with the first term, since it contains r^2 in the denominator, and we have

$$H' = \frac{4\pi I}{r\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \dots\dots\dots (9)$$

Equation (9) gives the magnetic force for points in the plane perpendicular to the current element under consideration, and for any other points in space, as that marked P in the figure, we have

$$H' = \frac{4\pi I}{r\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \dots\dots\dots (10)$$

The above expression represents the magnetic force due to a single element of the conductor, and for a conductor of length l we have

$$H = \int_0^l H' dl = H' l,$$

hence

$$H = \frac{4\pi I}{r} \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \dots\dots\dots (11)$$

In the derivation of the above expression for the magnetic field it was implicitly assumed that the current was uniform along the entire length of the conductor. To allow for the variation in the current distribution on the conductor we multiply equation (11) by a factor α , and so we finally have

$$H = \frac{4\pi I\alpha}{r} \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \dots\dots\dots (12)$$

In case of the Hertzian radiator whose length is very small

compared with the wave-length, we may put $a = \frac{1}{2}$, and equation (12) reduces to

$$H = \frac{2\pi I}{r} \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut-r) \sin \theta \dots\dots\dots (13)$$

For a sine distribution of the current on the oscillator,

$$a = \frac{2}{\pi}.$$

We can obtain the expression for the electric force around the oscillator by applying the principle of conservation of energy.

We have for the electromagnetic energy in an element of volume,

$$W_m = \frac{1}{8\pi} \mu H^2 \dots\dots\dots (14)$$

and for the electrostatic energy in the same element of volume,

$$W_s = \frac{K}{8\pi} E^2 \dots\dots\dots (15)$$

By equating the two equations (14) and (15) we get

$$E = \sqrt{\frac{\mu}{K}} H \dots\dots\dots (16)$$

For free space we have $\mu = 1$, and $K = 1$ or u^2 , depending whether we express E in electrostatic or electromagnetic units, hence

$$\begin{aligned} E &= H \text{ in electrostatic units} \\ &= uH \text{ in electromagnetic units} \end{aligned}$$

Substituting the value of H from (12), we get

$$E = \frac{4\pi I a}{r} u \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut-r) \sin \theta \dots\dots\dots (17)$$

and for a Hertzian oscillator we take $a = \frac{1}{2}$ and

$$E = \frac{2\pi I}{r} u \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut-r) \sin \theta \dots\dots\dots (18)$$

Equations (12) and (18) give the expressions for the magnetic and electric forces, in C.G.S. electromagnetic units, around a cylindrical oscillator. It will be shown further on that these expressions are identical with those given by Hertz.

ENERGY RADIATION.

Poynting established an important theorem concerning the energy transmission through an electromagnetic field, which is as follows:

If the energy of the electric strain and magnetic flux are

varying, then for any small element of volume in the field the amount of energy which enters each element of surface is measured by the product of the electric and magnetic forces resolved along each element of surface, multiplied by the sine of the angle between their directions, and divided by the numerical factor 4π . Integrated for the entire surface,

$$W = \frac{1}{4\pi} \int EH \sin \psi dS.....(19)$$

where ψ is the angle between the direction of the electric and magnetic forces, and dS is an element of surface.

For some distance from the oscillator the electric and magnetic forces are at right angles to each other, and therefore $\sin \phi = 1$. Hence

$$W = \frac{1}{4\pi} \int EHdS.....(20)$$

Suppose, now, we take a sphere of radius r described around the oscillator, and seek to determine the energy that escapes from that sphere. The energy radiated during the time dt from a spherical zone comprised between the angles θ and $\theta + \delta\theta$ is given by the expression

$$\delta W = 2\pi r \sin \theta. r d\theta. \frac{1}{4\pi} EH.....(21)$$

and to obtain the total energy radiated during the time dt it is necessary to extend the integration of the above expression for the entire surface of the sphere,—that is, integrate between the limits 0 and π . Hence

$$W = \frac{2\pi r^2}{4\pi} \int_0^\pi EH \sin \theta d\theta dt.....(22)$$

Substituting in (22) the values of E and H from (17) and (12), we get

$$W = 8\pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} \int_0^\pi \cos^2 \frac{2\pi}{\lambda} (ut - r) \sin^3 \theta d\theta dt.....(23)$$

But

$$\int_0^\pi \sin^3 \theta d\theta = - \left[\frac{1}{3} \cos \theta (\sin^2 \theta + 2) \right]_0^\pi = \frac{4}{3}.....(24)$$

hence the energy that escapes through the entire sphere in the time interval dt is

$$W = \frac{32}{3} \pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} \cos^2 \frac{2\pi}{\lambda} (ut - r) dt.....(25)$$

The energy radiated in a complete period is

$$W = \frac{32}{3} \pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} \int_0^T \cos^2 \frac{2\pi}{\lambda} (ut-r) dt \dots \dots \dots (26)$$

But

$$\begin{aligned} \int_0^T \cos^2 \frac{2\pi}{\lambda} (ut-r) dt &= \frac{\lambda}{2\pi u} \left[\frac{1}{2} \frac{2\pi}{\lambda} (ut-r) + \frac{1}{4} \sin \frac{4\pi}{\lambda} (ut-r) \right]_0^T \\ &= \frac{\lambda}{2\pi u} \frac{1}{2} \frac{2\pi}{\lambda} uT = \frac{T}{2} \dots \dots \dots (27) \end{aligned}$$

hence

$$W = \frac{16}{3} \pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} T \text{ ergs per period} \dots \dots \dots (28)$$

The energy radiated in one second is

$$W = \frac{16}{3} \pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} Tf = \frac{16}{3} \pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} \text{ ergs per second} \dots \dots \dots (29)$$

Expressing the current in ampères and the energy in watts, we have

$$W = \frac{16}{3} \pi^2 a^2 \frac{I^2}{100} \times 3 \times 10^{10} \frac{l^2}{\lambda^2} \frac{1}{10^7} = 1579 a^2 I^2 \frac{l^2}{\lambda^2} \text{ watts per second} \quad (30)$$

The energy radiated is directly proportional to the square of the length of the oscillator and the square of the current, and inversely as the square of the wave-length. For any particular value of $\frac{l}{\lambda}$ the energy dissipated by radiation is proportional to the square of the current in the oscillator, which is analogous to the case of energy dissipation by a resistance, and we may consider then the factor $1580 \frac{l^2}{\lambda^2} a^2$ as an equivalent resistance, and it is called the radiation resistance.

For $a = \frac{1}{2}$ we have for the radiation resistance

$$R = 394.8 \frac{l^2}{\lambda^2} \text{ ohms}$$

or in round numbers,

$$R = 400 \frac{l^2}{\lambda^2} \text{ ohms.}$$

$$\text{For } a = \frac{2}{\pi},$$

$$R = 640 \frac{l^2}{\lambda^2} \text{ ohms.}$$

Hertz gave the following expressions for the electric and magnetic forces around an oscillator, and the energy radiation:¹

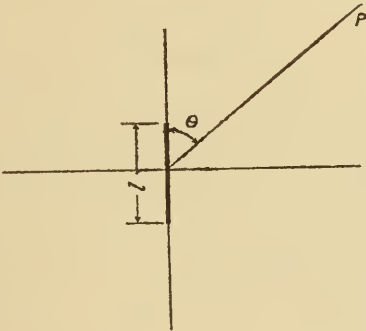
The electric forces,

$$Y = \frac{\phi m^2}{r} \sin (mr - nt) \sin \theta \cos \theta,$$
$$X = \frac{\phi m^2}{r} \sin (mr - nt) \sin^2 \theta.$$

The resultant electric force is

$$E = \sqrt{X^2 + Y^2} = \frac{\phi m^2}{r} \sin (mr - nt) \sin \theta. \dots\dots\dots (31)$$

FIG. 1.



The magnetic force,

$$H = \frac{\phi mn}{ur} \sin (mr - nt) \sin \theta \dots\dots\dots (32)$$

Energy radiation in one period,

$$W = \frac{16\phi^2\pi^4}{3\lambda^3} \dots\dots\dots (33)$$

where ϕ is the electric moment, the maximum charge on either end of oscillator multiplied by the length of the oscillator,

$$\phi = Ql. \dots\dots\dots (34)$$

Q is the charge expressed in electrostatic units. Expressing ϕ in electromagnetic units, we have

$$\phi = Qul. \dots\dots\dots (35)$$

¹ See J. A. Fleming, "Principles of Electric Wave Telegraphy and Telephony," second edition, chapter v.

If we denote by I the current in the conductor, and $\omega = 2\pi \times$ frequency, we have

$$I = \frac{dQ}{dt} = \omega Q,$$

and

$$\phi = \frac{Iul}{\omega} \dots\dots\dots (36)$$

In the notation used by Hertz and given in equations (31) to (33),

$$m = \frac{2\pi}{\lambda} \text{ and } n = 2\pi \times \text{frequency.}$$

On substituting the values of ϕ , m , and n as given above into equations (31) to (33), the equations will become identical in form with those given by (13), (18), and (30).

ANTENNÆ.

Practical experience has shown that the theoretical formulæ which have been derived above for a small oscillator may be applied with considerable accuracy in the study of the distribution of electromagnetic forces around antennæ of the different types that are now generally employed in wireless stations, providing we consider only points which are at some distance from the antenna. If we take the case of a single grounded vertical wire, we may consider the surface of the earth as the neutral plane of zero potential, corresponding to the neutral plane passing through the centre of a Hertzian oscillator, the antenna forming one-half of the oscillator and its image below the surface of the earth the other half of the oscillator. Obviously in this case it is only the upper half of the oscillator that contributes to the electromagnetic forces and the energy radiation, hence in applying the formulæ given above for this case we must use for l the length of the antenna and not twice its length, which is the length of the equivalent oscillator. Now, it can be readily shown that the fundamental free oscillation on a conductor, which is grounded at one end and open at the other end, has a wavelength which is four times the length of the conductor. The current has zero value at the open end and a maximum value at the grounded end, following a sine variation along the entire length. The average value of the current for the entire length of the conductor is $\frac{2}{\pi}$ times its maximum value, hence the value

of the factor α which enters in equation (30) is $\frac{2}{\pi}$. The energy radiated from the antenna during one period is

$$W = 640 I^2 \frac{l^2}{\lambda^2} \text{ watts} \dots\dots\dots (37)$$

and the radiation resistance is

$$R = 640 \frac{l^2}{\lambda^2} \text{ ohms} \dots\dots\dots (38)$$

where l is the height of the antenna. The above formulæ may be also applied to the different types of branched antennæ, providing the proper value of l is used in each case.

RADIATION DECREMENT.

In the case of free oscillatory currents in an electric circuit, the electrical energy originally stored in the circuit is gradually dissipated by the resistance of the circuit. The amplitudes of successive oscillations gradually diminish in amplitude until the entire energy is used up. The logarithmic ratio of the amplitudes of two successive oscillations is called the logarithmic decrement of the circuit. If we denote by I_1, I_2, I_3 , etc., the amplitudes of the currents of successive oscillations, we have

$$\frac{I_1}{I_2} = \frac{I_2}{I_3} = \frac{I_3}{I_4} = \text{etc.} = e^{\delta} \dots\dots\dots (39)$$

where δ is the logarithmic decrement, and is expressed by the following formula:

$$\delta = \frac{R}{2Lf} \dots\dots\dots (40)$$

where R is the resistance of the circuit expressed in ohms, L is the inductance of the circuit expressed in henry and f is the frequency of the oscillations. The value of δ as given by (40) is the logarithmic decrement per complete period. In the case of a vertical single-wire antenna grounded at the lower end, the fundamental wave-length developed by a free oscillation is four times the length of the antenna. We have

$$\lambda = 4l$$

and

$$R = 640 \frac{l^2}{\lambda^2} = 640 \frac{l^2}{16l^2} = 40 \dots\dots\dots (41)$$

For the frequency of the oscillations we have

$$f = \frac{u}{\lambda} = \frac{3 \times 10^{10}}{4l}, \dots\dots\dots (42)$$

and the value of the inductance is given by the expression

$$L = 2l \left\{ \log_{\epsilon} \frac{2l}{r} - 0.75 \right\} \times 10^{-9} \text{ henry}, \dots\dots\dots (43)$$

where r is the radius of the conductor. As an approximation we may neglect 0.75 in comparison with $\log_{\epsilon} \frac{2l}{r}$ in equation (43). Substituting the values of R , f , and L , from equations (41) to (43) in equation (40), we get

$$\delta = \frac{40}{4l \log_{\epsilon} \frac{2l}{r} \times 10^{-9} \times \frac{3 \times 10^{10}}{4l}} = \frac{4}{3} \frac{1}{\log_{\epsilon} \frac{2l}{r}} \dots\dots\dots (44)$$

Equation (44) gives the logarithmic decrement for the fundamental oscillations of the current,—that is, the quantity $\epsilon^{-\delta}$ gives the ratio of the amplitudes of two successive oscillations. Since the energy of each oscillation is proportional to the square of the current, the radiation decrement is twice the value given by equation (44). The ratio of the energies of two successive oscillations is $\epsilon^{-2\delta}$, and 2δ is therefore the radiation decrement. We have then

$$\delta_{\epsilon} = 2\delta = \frac{8}{3} \frac{1}{\log_{\epsilon} \frac{2l}{r}} = \frac{2.67}{\log_{\epsilon} \frac{2l}{r}} \dots\dots\dots (45)$$

The problem of antenna radiation was discussed by Dr. M. Abraham,² who treated the problem in a very original manner, and he obtained an expression for the radiation decrement of the fundamental frequency of the oscillations corresponding to equation (45), which is as follows:

$$\delta_{\epsilon} = \frac{2.44}{\log_{\epsilon} \frac{2l}{r}} \dots\dots\dots (46)$$

Equations (45) and (46) give very nearly the same value for the radiation decrement; they are exactly of the same form, differing only by a small numerical factor.

WASHINGTON, D. C.

² M. Abraham, *Physikolische Zeit.*, 1901.

THE FLOW OF SANDS THROUGH ORIFICES.*

BY

ERNEST A. HERSAM,

Associate Professor of Metallurgy, University of California,
Member of the Institute.

THE flow of dry sands and like substances through orifices, under varied conditions and different sand-heads, has not been studied sufficiently for predicting results. It is desirable to know (1) the rate of flow of dry sands under definite conditions, (2) the extent of the variation in flow under varying conditions, (3) the influence of the physical qualities of the sands, and (4) the form and size of required discharge-orifices to permit of unfailing flow or other desired results. So far as practicable it is desirable to have numerical constants at one's command to represent the separate influences that work upon the result. Such influences require separate recognition, and are made the objects of study described in the pages which follow.

Appliances for Measuring the Flow.—The three forms of appliance which were used for determining the rate of flow in the tests to be described are illustrated in Figs. 1, 2, and 3. The appliance shown in Fig. 1 was used with discharge-orifices of one-half inch or less in diameter. The arrangement shown in Fig. 2 was used with orifices larger than one-half inch diameter, and, in certain tests of a special nature, with orifices smaller than this. The appliance shown in Fig. 3 was used in certain small tests of limited application.

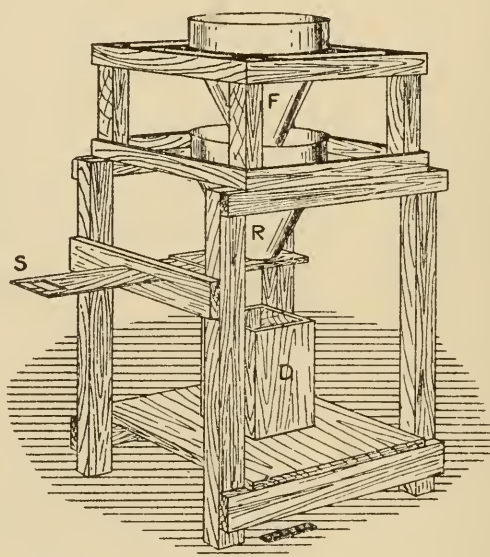
The appliances were checked, one against another, under various conditions, testing the same discharge-orifices in each. They were modified, moreover, in various ways to comply with the requirements of certain special tests which are to be described. Under all the regular conditions of operating, the depth of sand above the discharge-orifice was twelve times the diameter of the orifice.

In the apparatus shown in Fig. 1, the conical receptacle *R*, which is $12\frac{1}{2}$ inches in diameter at the top, $3\frac{1}{4}$ inches at

* Communicated by the author.

the bottom, and $12\frac{1}{2}$ inches deep, is the reservoir supplying the material to the discharge-orifice in the centre of the bottom. The orifice plates, in which the orifices are formed, are shown in Fig. 4, under the letters *j* to *q*. These, except where otherwise stated, are brass discs, with the orifices turned or drilled in the centre, forming a ring. The orifice plates fit interchangeably into a recessed seat in the centre of the bottom of the truncated cone *R*. Thus the bottom of the cone *R*, when the orifice plate is in place, is flat over a diameter of $3\frac{1}{4}$ inches. The discharge is controlled by the slide *S*. The upper cone, *F*, is used to supply material to the lower cone, *R*, and to regulate

FIG. 1.

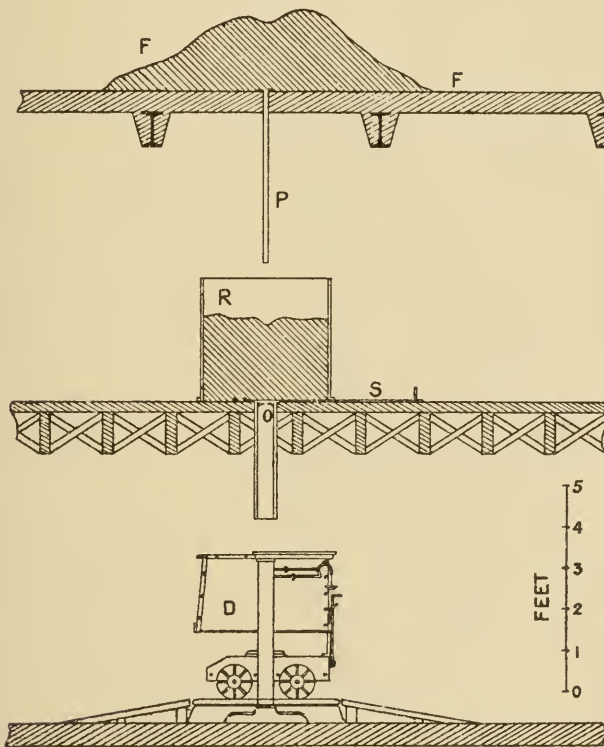


the level of the material in the cone *R*. The supply of flowing material enters the reservoir *R* through a regulated opening in the bottom of the cone *F* at the level desired.

In the arrangement shown in Fig. 2, the bin *R*, three feet in each of the three dimensions, supplies the material at the discharge orifice *O*. The orifice plates are interchangeable in this appliance as in the foregoing one. Here, as in the previous case, the orifice plate fits into a turned seat, and is thus supported in a horizontal position, with the aperture opening vertically downward. Material is supplied to the bin *R* from the floor above at *F*. The bin *R*, shown in the figure, is replaced by one of another form, deeper, and of smaller area, for certain

special tests on the influence of the sand-head which are to be described. Different ways of supplying the material to the bin *R* were examined and made use of according with the purpose. The pipe *P* was used as a means of supplying the material in the usual tests. When it was necessary to break the impact of material entering the bin *R* through the pipe *P*, a large tee pipe-fitting was attached to the lower end of the pipe. The material discharged from the standard orifice, at *O*, was re-

FIG. 2.



ceived in the car *D*, or in other tared receptacles in accord with the quantity for weighing.

The arrangement shown in Fig. 3 was used for certain small tests with small orifices. It was used whenever a volumetric measurement of the flowing material was directly sought. Further use was made of the arrangement in determining the density of sands in the dry, aggregated state, as will be described.

Outline of Tests to Determine the Flow.—Provision is made in the appliances shown in Figs. 1 and 2, to secure a full

and regular stream of the sand or other material, flowing under constant conditions, vertically downward, through an accurately-formed orifice of the selected size and shape. Provision is further made to arrest or divert the flow and to receive the material, for an accurately-timed period, in a receptacle for accurate weighing.

To determine the flow by means of the appliance shown in

FIG. 3.

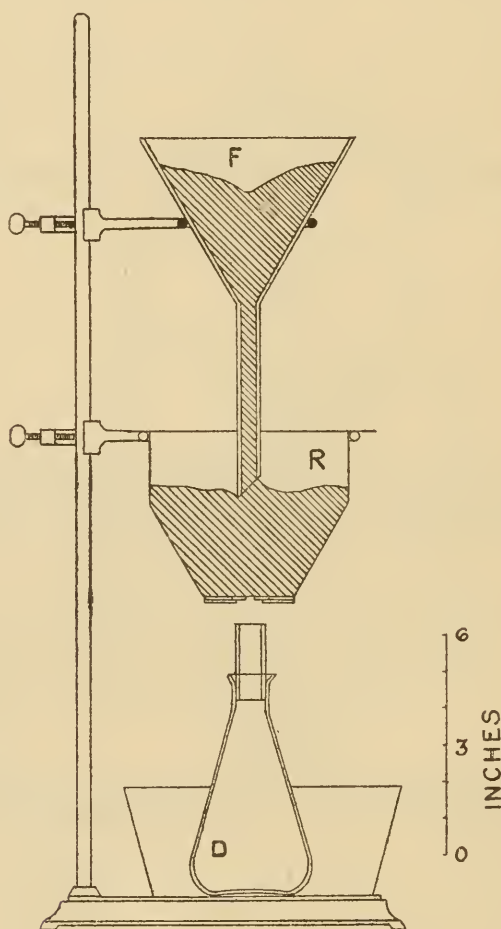


Fig. 1, the slide *S* is first drawn, and the stream allowed to become regular, whereupon, at a definite moment, the empty receptacle *D* is inserted beneath the stream. The flowing stream then entering the receptacle is allowed to continue the desired time, as measured by a stop-watch. The stream is then arrested by throwing the slide *S*. The quantity of material thus collected is weighed, and from the weight is learned the volume as based upon the known density of the aggregated material, determined

under conditions to be described. The volume of material which has passed the orifice of known area in a given time thus being known, the velocity of the stream, in feet per second, is calculated.

To determine the flow by the use of the arrangement shown in Fig. 2, the stream is started and stopped by means of the slide S. Here the duration of the flow is relatively long. The time is measured accurately with the stop-watch. In certain tests with small orifices, to determine the velocity of flow under a varied head, the stream was made continuous, but was deflected for definite periods at fixed intervals into a receptacle below.

In using the appliance shown in Fig. 3, the stream was made continuous. The small size of the containing vessels and the manner in which the apparatus was used permitted of accurate time-measurement without the special mechanical means to divert or arrest the stream. The appliance was used primarily as a means of supplying a stream of material for the determination of the density, as will be described, but was used in a limited way for obtaining results by volume to accord with those by weight in the usual tests.

In the determination of the flow directly by volume, the flask D, graduated, and of 325 c.c. capacity, was inserted at the designated moment beneath the flowing stream. The time was noted of the instant at which the stream began to enter and at which the flask became filled to the graduation mark at the top. The height of the fall of the material from the orifice into the flask was adjusted, as well as could be, to accord with that of the same material under the conditions of determination of density that are adopted as standard and are later to be described. When thus standardized, the appliance as here shown was found suitable to use for certain tests conducted in a series, with an orifice of one size, on materials of one type.

The sand materials which were tested were prepared in all cases by dry sizing upon closely-graded wire screens. The estimate of the diameter of the particles was made by direct measurement under magnification. A comparison of this measurement with the screen measurements was made in every case, and in certain cases by volumetric displacement of numbers of the particles. The results of the average direct measurement are adopted as the best expression of size.

The Precision of Measurement and the Accuracy.—The separate observations of flow were repeated in each case to obtain four to nine independent results. These results were averaged, and the average deviation from the mean in each case was observed. In these tests an aggregate of ten minutes was adopted as a minimum duration of flow, the time beyond this being given according to the requirement shown by the deviation among single observations. The time was measured with a correct stop-watch, giving precision to $\frac{1}{5}$ second.

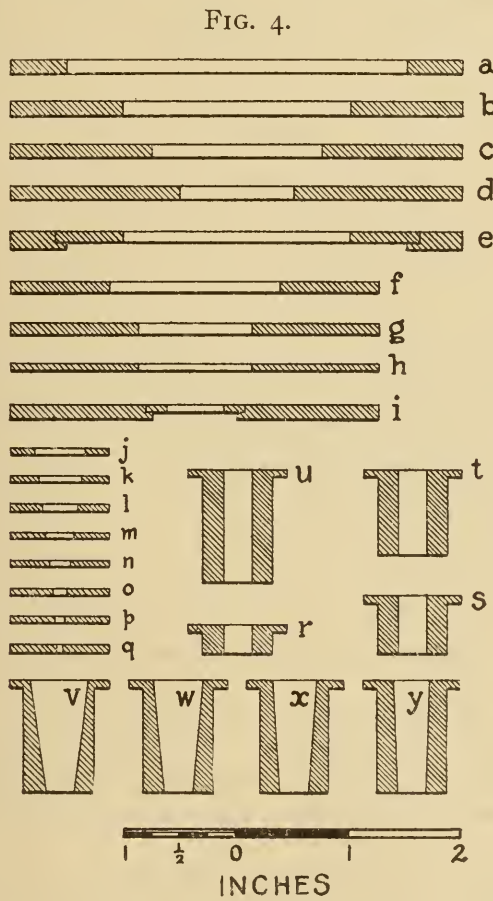
The limit to the accuracy of the observations is imposed by the construction of the discharge-orifices, and by the assurance of quality and the measurement of the coarseness of the sands. The orifices are accurate in construction to $\frac{1}{1000}$ inch in dimensions. The limit to the accuracy of the construction and measurement of these introduces the possible error of one part in approximately 250 with the $\frac{1}{4}$ -inch orifice, to one part in approximately 3000 with the 3-inch orifice. Certain of the smaller orifices were duplicated for replacement and comparison. The precision as to time-measurement and weighing exceeds that necessary to accord with the accuracy of the orifices. With materials of varied coarseness, tested for a comparison of the influence of the size of the grains, the limit to accuracy is imposed by the sizing and preparation of the material and the estimate of the size of the constituent grains.

The deviation in the rate of flow was different in the observations upon different substances, as will be described, and ranged from one part in thirty to the limit of precision of the observations, in which one part in one thousand was sought wherever compatible with the exactness of the orifice or with the uniformity and character of the material. With a long duration of flow the deviation among observations was shown to be less wide, the decrease, however, not continuing with greatly increased time. The duration of flow employed was chosen as ample to equalize the brief irregularities of flow, and to be consistent with the accuracy in the remaining conditions.

The value of the acceleration of gravity at the place of determination approximates 9.7996 metres per second. The atmosphere is that of a dry interior. The daily variation in the humidity of the interior atmosphere is unrecorded, as

are also the variations in barometric pressure; the differences in temperature are between 12° and 22° C.

The Discharge-orifices.—The discharge-orifices chiefly intended for study were of circular cross-section. In addition to these, a square, a triangular, and certain oblong forms were used for comparison. The orifices were prepared with a smooth finish, made as nearly uniform as possible in all. With the exception of the few special forms to be described, they were

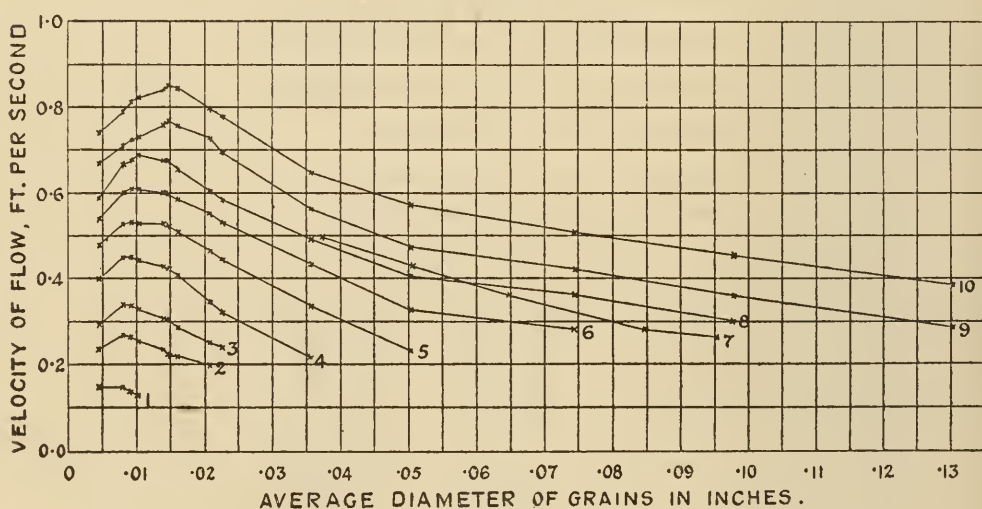


made without taper, by cutting the aperture in the centre of round, turned discs of rolled brass. These discs were of 1/16 inch thickness for orifices of 1/2 inch or less in diameter, 3/32 inch for those between 1/2 and 2 inches, and 1/8 inch for sizes larger than 2 inches. Each fitted into a turned seat provided in each of the forms of appliance, the smaller orifices being extended by means of turned rings to the size of the seat in the larger apparatus, as shown under the letter *i* in Fig. 4, the de-

sideratum in each case being to maintain a flat bottom of the receptacle to the sand material contained. The orifice plates, thus interchangeable, remain rigid in a horizontal position such as to direct the stream vertically downward.

Several orifices, other than of the round forms described, are shown in Fig. 4. Under the letters *v* to *y* are round, tapered orifices. Those lettered from *r* to *u* are of $\frac{1}{4}$ -inch diameter, circular in cross-section, and of varied length. The triangular orifice, two rectangular forms, and a round orifice not shown were made of a uniform cross-sectional area of one-quarter of one square-inch.

DIAGRAM I.



- | | |
|---|---|
| 1. River sand, $\frac{1}{8}$ inch orifice. | 6. River sand, $\frac{5}{8}$ inch orifice. |
| 2. River sand, $\frac{3}{32}$ inch orifice. | 7. Lead shot, $\frac{3}{8}$ inch orifice. |
| 3. River sand, $\frac{1}{4}$ inch orifice. | 8. River sand, $\frac{7}{8}$ inch orifice. |
| 4. River sand, $\frac{3}{8}$ inch orifice. | 9. River sand, $\frac{7}{16}$ inch orifice. |
| 5. River sand, $\frac{1}{2}$ inch orifice. | 10. River sand, $\frac{1}{2}$ inch orifice. |

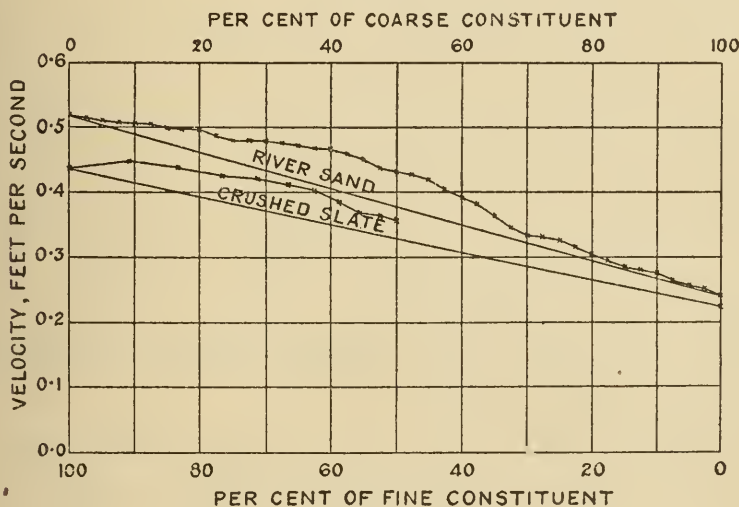
Tests with Sand of Varied Coarseness.—Diagram I shows the velocity of flow, in feet per second, of river sand, in passing round discharge-orifices, after being sized as closely as possible by dry screening. In comparison is shown the velocity of lead shot, after being carefully prepared and measured as described under Table I.

The river sand here used consists of naturally worn and rounded grains, rendered free from dust or clotted clay particles by washing and mechanical treatment, and freed from moisture by long exposure to a dry atmosphere. The sized products of

the sand were obtained by a systematic and thorough dry-sizing treatment, upon measured, closely-graded, brass-wire screens, and the average diameter of the grains is arrived at in an average of the measurements of many of the particles. The orifices were of turned brass, without taper, as shown under the letters *i* to *q* in Fig. 4, and were so placed as to direct the stream vertically downward in the apparatus shown in Fig. 1.

The results in velocity of flow were derived from the weight of sand discharged during periods of ten minutes, or shorter periods aggregating ten minutes or more, and were calculated from this weight and from the known specific gravity of the material in the dry, aggregated state. The limit to the accuracy

DIAGRAM II.



of the tests is reached in the variability in the quality of the materials. The precision of the observations as to time, weighing, and measurements exceeds one part in three hundred.

The Effect of the Mixture of Sizes.—Diagram II shows the effect upon the velocity of flow of a disparity in the size of the grains of sand. Sized products, coarse and fine, of river sand in one series of tests, and of crushed slate in another, are mixed in different proportions to observe the effects of the mixture of sizes upon the velocity of flow.

Diagram II represents in ordinates the velocity of flow through a $\frac{1}{4}$ -inch round orifice, in feet per second, and in abscissæ the per cent. of coarse and of fine grains in the mixture. The straight line between the two extremes shows the velocity

as it would be if proportionate to the amount of each sized product composing the mixture. The two curves represent the two types of material,—river sand in the one case, and crushed slate in the other.

The river sand here used was identical in quality with that described in connection with Diagram I. Of the sand, two closely-sized products obtained with graded screens were used, which differed only in regard to coarseness. The average diameter of the particles, as determined by measurement, was .0503 inch in the case of the coarse and .0149 of the fine sand. The two products, coarse and fine, were then combined in varied proportions by weight, as represented in the diagram. The combined products, in each case, were then mixed thoroughly to give the uniformity sought.

The crushed slate, similarly, was present in two degrees of coarseness. The grains are angular, and the average diameter of the grains, as determined by many measurements, is .0468 in the case of the coarse product, and .0166 in the case of the fine. The coarser of the two materials, when unmixed with the fine, is at the limit of size permitting of assured, continuous flow through the $\frac{1}{4}$ -inch orifice which was used. As in the case of the river sand, the coarse and fine sands in different proportions were thoroughly mixed before undertaking the determination of the velocity.

The results in these cases were averaged from nine or more observations by volume, taken by the use of the apparatus shown in Fig. 3. The results were checked in some of the cases by observations based upon weight, in which the specific gravity of the mixture was determined by the method adopted as standard throughout the work, and to be explained. The deviations of the single observations from the mean, in the present instance, were for the most part less than one part in one hundred in the case of the river sand, and with the finer product of the slate, but increased in the case of the coarse slate to one part in thirty, with more than 50 per cent. coarse material present, beyond which the curve is not extended.

The Influence of the Size and Surface of Spherical Pellets.—Table I shows the results of tests with lead shot, flowing from a $\frac{3}{8}$ -inch round orifice. The shot is chosen as a material composed of particles relatively uniform in shape.

The velocity shown in Table I is calculated from the mean observed weight of shot flowing during periods of two minutes, the calculation being based upon the density of the material under constant conditions, as will be described later. The density of the shot, which varies in the aggregated mass with the condition of the surface of the pellets and depends upon the manner in which the material is prepared for the observations, is given in the fifth column in Table I, and ranges from 6.64 to 6.80. The diameter of the approximately spherical pellets of shot, as shown in Table I, was derived by weighing together 100 of the pellets and calculating from the average weight of these, and upon the basis of the determined specific gravity of the lead, assuming the pellets to be spherical. The average variation in the diameter from the mean was obtained by the separate weighing of ten of the pellets of each kind.

TABLE I.

Table Showing the Velocity of Flow of Lead Shot, of Varied Sizes, through $\frac{3}{8}$ -inch Round Orifice.

The diameter of the pellets of shot.				The density of the shot in mass.	Average velocity in feet per second.		
Average of 100 pellets.	Maximum observed.	Minimum observed.	Average deviation from the mean.		In the condition purchased.	After washing and drying.	After washing and drying and coating with graphite.
.0952	.0964	.0930	.0009	6.802	.264	...	.265
.0850	.0861	.0843	.0008	6.722	.280	.266	.284
.06488	.0664	.0629	.0010	6.648	.364	.341	.363
.05057	.0532	.0448	.0014	6.761	.413	.408	.433
.03710	.0401	.0259	.0022	6.645	.504	.480	.498

The portions of shot of different size were all mechanically treated in order to produce a uniform condition of the surface. After the first observations of the velocity of the material in the original condition, the portions were treated alike by agitation with distilled water and soap as a detergent, then rinsed with water, followed with alcohol, and finally dried at 100° C. After testing in this condition to observe the velocity of flow, each portion was treated with graphite to thoroughly coat the pellets. The results upon the material as thus treated are shown in Table I.

The apparatus used was of the form shown in Fig. 3, except that a larger and open receptacle was used below the orifice for collecting and weighing. The operation was conducted otherwise, as is described in explanation of Table I. Here, however, with relatively little material, no mechanical attachment was required to arrest or start the stream, it being satisfactory to collect the flowing material in the required time by inserting and removing the receptacle beneath. The results as averaged are accurate to one part in four hundred. These are illustrated also in comparison with those obtained with sand in Diagram I.

The state of the surface of the shot was known to be an important influencing condition, determining in a large measure the coefficient of friction and the cohesion of the separate particles and thus exerting an important influence upon the density of the material and upon the quantity discharged. To observe the effects of extremes, and to judge as to requirements of prepared surfaces, tests were made, with results shown in Table II.

TABLE II.

Table Showing the Effect of the State of the Surface of Pellets of Lead Shot upon the Velocity of Flow.

The quality of the surface of the shot pellets.	Average velocity in feet per second.
In the original condition.....	.364
Slightly damp.....	.338
Moist.....	.295
Washed and dry.....	.341
Coated with rosin.....	.317
Freshly coated with graphite which is present in excess.....	.380
Freshly coated with graphite with excess graphite removed....	.364

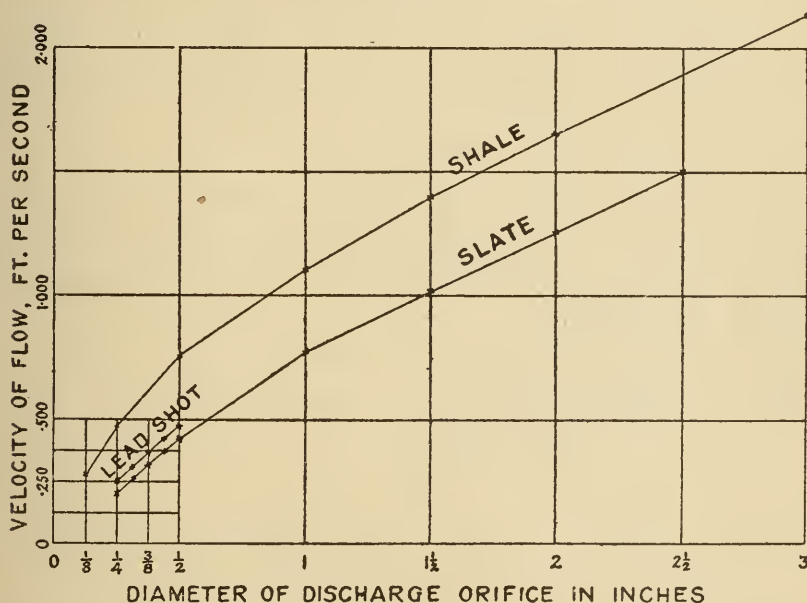
Table II shows the effect of the varied surface conditions upon the velocity of flow of lead shot through the $\frac{3}{8}$ -inch round orifice. The shot pellets were .06488 inch in diameter, and varied from the mean approximately one part in sixty. The velocity, as before, was determined by weighing the material collected in a given time, calculating the velocity from the area of the orifice and the density of the material in the state prepared for the special observations as will be described. The results are accurate to one part in two hundred.

The Size of the Orifice Related to the Velocity of Flow.—Tests were conducted to show the influence of the size of round orifices upon the velocity of flow. Diagram III shows the

velocity of flow of closely-sized, crushed slate, of fine-crushed shale, and of lead shot in passing round orifices of varied sizes.

The crushed slate represented in Diagram III was dry from long contact with the air after close sizing with wire screens. The particles were irregular and angular in shape, and were .0468 inch in the average diameter of the average grains. The velocities plotted are averaged from four to nine observations, according in number with the variation in flow and the deviation of the single observation. The averaged results may be considered accurate to one part in three hundred, while the precision as to time and weight considerably exceeds this. The sand-head, as in all the regular tests, was twelve times the diameter of the orifice employed.

DIAGRAM III.



The crushed shale represented in the above diagram was crushed and screened to exclude particles incapable of passing a screen of .014 inch (40-mesh) opening. The purpose was to work with fine-crushed material with a wider range of orifices. The material was composed of irregular grains, and included the undersize. The size and quality of the material were judged by screen tests performed upon different samples, and the portions employed for tests were so mixed as to represent material of a uniform quality and kind. The apparatus used in the tests upon the two sand materials is shown in Fig. 2, and was employed

in the manner previously described. The round orifices are shown in Fig. 4 under the letters *a* to *d* and *i* to *o*.

The lead shot represented in Diagram III is of the quality previously described under Table I. The velocity is derived from the averaged weight flowing during periods of two minutes. The averaged diameter of the pellets is .0649 inch. The surface of the pellets is in the state prepared in manufacture for the trade. The results are accurate to one part in 250.

Tests of Materials of Varied Density.—The velocity of flow of several substances of varied specific gravity was determined for the purpose of comparison. The results obtained with lead shot, as a material of high density, and mustard seed, of nearly similar spherical shape and of low density, were found best to illustrate the effects. With these materials many of the interfering conditions could be eliminated which with other substances obscured the effects of density alone. Table III shows the velocity of flow of lead shot in comparison with that of mustard seed of a corresponding size.

TABLE III.

Showing a Comparison of the Velocity of Flow of Lead Shot and of Mustard Seed, of the Same Size, Passing a Round Discharge Orifice of $\frac{3}{8}$ inch Diameter.

Substance.	Diameter of pellets.	Approximate mean variation in diameter of the pellets.	Condition of the surface.	Average velocity in feet per second.
Lead shot.....	.0850	1 : 100	As prepared in manufacture	.280
Lead shot.....	.0850	1 : 100	After agitation with the mustard seed and graphite, and separating.	.286
Mustard seed..	.085	1 : 30	The condition in which the material existed before the surface alteration.	.301
Mustard seed..	.085	1 : 30	After agitation with the shot and graphite and separating.	.282

To obtain the results of Table III, the grains of seed and the pellets of lead shot were selected of a size as nearly as possible identical. To prepare the seed, an adequate quantity was winnowed to remove dust, and sized as rigidly as possible to correspond with the nearest size of shot available. The seeds were further examined and selected by permitting them to roll

slowly down an inclined surface to expose repeatedly to the attention all that were of imperfect form. The diameter of the shot was determined by calculation based upon the combined weight of one hundred of the pellets of determined density, as previously described. The diameter of the mustard seed could not well be determined in a similar manner, by weight, on account of the variability in density of the different seeds. The size was measured as accurately as possible by means of a micrometer gauge, and also by checking by placing the round seeds, side by side, in a V-shaped groove and measuring the combined diameter of samples of fifty or more. The specific gravity of the lead shot, in the aggregated mass, inclusive of the interstitial air-space, was 6.722, while that of the mustard seed was 0.7276 in the corresponding condition. The diameter was 0.085 inch, that of the shot being more nearly uniform in the mass, and in the spherules themselves, and thus capable of closer approximation.

TABLE IV.

Table Showing the Velocity of Flow of Samples of River Sand and of Beach Sand through Round Discharge-orifices of Identical Size and Form Composed of Different Materials.

Material of the ¼-inch orifice.	Average velocity of beach sand, composed of grains averaging .026 inch diameter.	Average velocity of river sand, composed of grains averaging .023 inch diameter.
Hard rubber.....	.419	.394
Brass.....	.441	.422
Babbitt's metal.....	.453	.431

The head, as in other tests with the 3⁄8-inch orifice, was 4½ inches. The orifice was round, of brass, and identical with that of this size previously used and shown under the letter *k* in Fig. 4. The time of flow for each observation approximated one minute, depending upon the velocity, and was measured to 1⁄5 second precision. The results are averaged from some nine observations in each case, and as thus averaged and tabulated are accurate to one part in one hundred.

The Material of Discharge-orifices.—Round discharge-orifices of ¼ inch diameter were made of hard rubber, and of Babbitt's metal for comparison with those of brass. Table IV shows the velocity of flow observed with samples of beach sand and of river sand in passing these orifices.

The round orifices by which the above results were obtained were of $\frac{1}{4}$ inch diameter, cut without taper through material of $\frac{1}{16}$ inch thickness, and were of the form shown under the letter *m*, Fig. 4. They are of the same degree of accuracy as the brass orifices previously described, and are prepared as nearly as possible of a uniform surface finish among the different materials from which they are made. The sands used in the tests with these orifices were the closely-sized beach sand and river sand used in previous tests. The beach sand is composed of rounded grains of .026 inch in average diameter. The river sand is composed of grains of .023 inch average diameter. The results in velocity as here averaged and tabulated are accurate to one part in two hundred.

TABLE V.

Table Showing the Velocity of Flow of Beach Sand, Composed of Grains of .026 Inch Average Diameter, with Round Discharge-orifices of $\frac{1}{4}$ -inch Diameter, of Varied Length and Contraction.

The designating letter of the orifice, referring to Fig. 4.	Length of the orifice-tube, in inches.	Diameter of the discharge-orifice at the top, in inches.	Diameter of the discharge-orifice at the bottom, in inches.	Average velocity in feet per second.
<i>r</i>	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	0.44
<i>s</i>	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	0.44
<i>t</i>	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	0.44
<i>u</i>	1	$\frac{1}{4}$	$\frac{1}{4}$	0.45
<i>y</i>	1	$\frac{5}{16}$	$\frac{1}{4}$	0.86
<i>x</i>	1	$\frac{3}{8}$	$\frac{1}{4}$	1.09
<i>w</i>	1	$\frac{7}{16}$	$\frac{1}{4}$	0.94
<i>v</i>	1	$\frac{1}{2}$	$\frac{1}{4}$	0.82

The Effects of Tapered and of Elongated Orifices.—Table V shows the velocity of flow of beach sand in passing $\frac{1}{4}$ inch round orifices of different forms as indicated. The average velocity is expressed in feet per second.

The round discharge-orifices here used were of turned brass, and were of accuracy corresponding to that of the orifices previously described. The tests are similar to the preceding ones in method. The material is a portion of the sized beach sand previously described, composed of particles of .026 inch in average diameter. The results as here averaged may be regarded accurate to one part in two hundred.

The Influence of the Cross-sectional Shape of Orifices.—The effect of certain differences in the cross-sectional shape of orifices is shown in Table VI, for one kind of material and one size of orifice.

TABLE VI.

Table Showing the Influence of the Cross-sectional Shape of the Discharge-orifices upon the Velocity of Flow. (The Area of Each of the Five Orifices is Equal to One-Quarter of One Square Inch.)

Shape of orifice.	Velocity in feet per second.
Round.....	.482
Square.....	.454
Rectangular ($\frac{3}{8}$ by $\frac{2}{3}$ inch).....	.436
Equilateral triangular.....	.376
Rectangular ($\frac{1}{4}$ by 1 inch).....	.311

Table VI shows the velocity of flow of a uniform, closely-sized, crushed slate, issuing from orifices of uniform cross-sectional area but of varied cross-sectional shape. The orifices were cut through $\frac{1}{8}$ -inch brass plate, and were made to conform in accuracy with those previously described. The apparatus is shown in Fig. 1. The crushed slate, which is composed of grains of .0468 inch in average diameter, has been described previously. The results as averaged may be regarded accurate to one part in two hundred.

The Sand-head.—The practical influence of a varied sand-head upon the velocity of flow was tested with a variety of materials, under a variety of conditions, the details of which scarcely justify description in this place. The sand-head examined ranged between a height equalling twice the diameter of the discharge-orifice to one of seven feet. The orifices used were round, of $\frac{1}{4}$ to 2 inches in diameter. The effects observed under the varied head were in all cases relatively slight, being less than one part in fifty from the mean under any of the conditions of varying head with thoroughly dried material. The apparatus used for the tests, apart from certain modifications of the feeding bin above to obtain the column and the supply required, is shown in Fig. 2.

The effects in most cases were not influenced uniformly by the head. For the most part a retardation of the flow resulted from an increase of the head—an effect which appeared attributable to the compacting of the sands under the increased pressure

of a high column, and the segregation known to occur at the surface, particularly effective under the necessary conditions incident to a low column. A series of results upon fine, sized sands passing the $\frac{1}{4}$ -inch orifice was obtained in which the difference in head, between one-half inch and seven feet, was not distinguishable from the usual deviations observed under constant head.

The Effect of the Surface Contour.—A series of tests on a small scale was conducted to examine the effect of the contour at the surface and the influence of the shape of the supply receptacle. Fig. 5 illustrates the results.

FIG. 5.

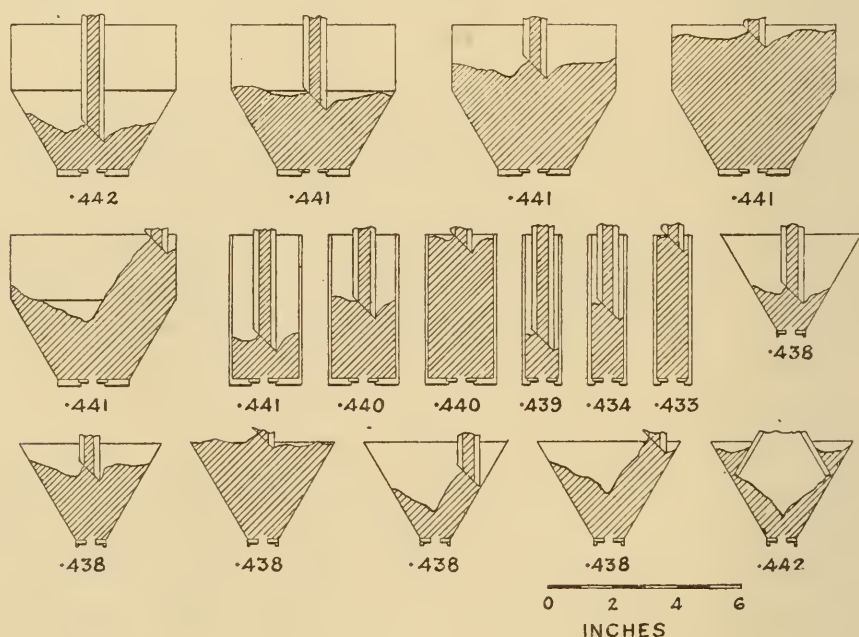


Fig. 5 represents vertical sections of the receptacles of sheet metal supplying the flowing sand to the brass orifice at the bottom. The round, brass discharge-orifice is of $\frac{1}{4}$ inch diameter, and of the form shown under the letter *m*, Fig. 4. The material tested is the closely-sized beach sand composed of particles .026 inch in average diameter, similar in kind to that previously used. Of the supply receptacles, two are seen to be truncated cones. The smaller cone is of $\frac{7}{8}$ inch diameter at the bottom, the larger cone $2\frac{1}{4}$ inches. Two of the receptacles are cylindrical, one being two inches in inside diameter, the other, one inch. The sand-head is indicated by the shaded portion of

the section, and ranges from one inch to four, in differences of one inch in the different cases. The material is supplied to the different supply receptacles from a funnel above, the position of which is indicated in each figure by showing the lower extremity of the stem at the surface of the material. The velocity of flow through the 1/4-inch brass orifice, in feet per second, is shown in numerals beneath each figure representing the conditions. The results averaged and shown are accurate to one part in four hundred.

TABLE VII.

Table Showing the Specific Gravity of Typical Sands, and Other Substances.

Material.	Dimensions in inches of the rectangular screen-openings through which the material was incapable of passing.	Dimensions in inches of the rectangular screen-openings through which the material passed.	Specific gravity of the dry, loose material, under the conditions of compacting described.	Specific gravity of the solid.	Ratio of the specific gravity of the aggregated mass to that of the solid.
River sand . .	.014	.021	1.376	2.71	508 : 1000
River sand . .	.007	.008	1.338	2.72	491 : 1000
Beach sand . .	.014	.021	1.432	2.66	538 : 1000
Crushed slate	.033	.042	1.380	2.75	502 : 1000
Crushed shale	.000	.014	1.256	2.61	481 : 1000
Lead shot . . .	.063	.067	6.722	11.13	604 : 1000
Pumice stone	.033	.042	0.504	0.87	579 : 1000

The Density of the Materials.—In all the foregoing observations it has been considered desirable to express the capacity of the discharge-orifices in terms of velocity. The velocity indicated applies thus to the volume of dry sand or like substance in aggregated mass of known density passing the orifices in a given time. The velocity, so stated, is computed for the cross-sectional area of the orifice which is definitely known in each case. Results so expressed can be converted into terms of quantity or weight by making use of the known density of the material. The quantity of material flowing in all ordinary tests was determined by weight, and from this weight was calculated the volume, as based upon the determined specific gravity of the material in the state of aggregation adopted as standard. Accordingly a study was made of the interstitial space of the materials for the adoption of a state of density to be regarded standard in the various tests.

To obtain the material in a uniform condition of compactness, suitable for a constant determination of the density, the particles were allowed to collect in a given receptacle in a uniform manner, becoming compacted only by their fall through a known distance. In this prepared state of aggregation, the density of all materials was determined as a basis for the estimation of the velocity of flow. The average density of certain of the typical materials is shown in Table VII.

The Method of Determining Density.—The material was collected for the determination of density by being permitted to flow, vertically, by gravity, through a discharge-orifice capable of yielding a continuous stream, and the stream received below the orifice, in a stationary cylindrical receptacle, in which the weight and volume were subsequently determined in the state of compactness thus acquired by the particles in lodgement. The orifices used in each case were selected from a given series of orifices graded in differences of $\frac{1}{8}$ inch diameter. These were required to be commonly eight or more times the diameter of the particles. The cylindrical receiving receptacles were prepared of a size to accord with the series of orifices, and were tared, standardized, and thus in accord with the coarseness of the given material. The cylinders were made of sheet metal, and were in depth twelve times the diameter of the chosen orifice, and in diameter ten times. They were supported in an upright position upon the closed end, distant below the orifice sixteen diameters of the orifice, the entire top of the cylinder being open. The material thus collected in the receptacle was afterward levelled by scraping off the excess above the rim at the top with a bevelled straight edge before disturbing the content in a way to alter the density. The receptacle, with its content, was then weighed, and the density of the material calculated from the known capacity of the receptacle. The observations were concordant in most cases to one part in two hundred. The determinations were repeated to obtain an average result consistent in exactness with the tests to be performed upon the materials.

Moisture.—Tests were conducted to show the influence of moisture in quartz river sand, shale, and other materials in different states of desiccation. The results show an increasing

velocity with an increasing degree of desiccation. The state of extreme desiccation is found to be insufficiently permanent to yield concordant results in open tests. In the recorded tests the materials are dry from long contact with dry air at the ordinary interior temperature of 17 to 20° C. A degree of uniform drying is thus brought about at which the hygroscopic quality of the surface of the particles and the desiccating effect of the dry atmosphere at the ordinary temperature are in such equilibrium as to occasion no appreciable change in the state of the material by exposure to the atmosphere during the tests.

The Rate of Discharge.—The weight of material passing an orifice in a given time may be calculated for round orifices from the results in velocity as shown in the diagrams and tables. For orifices of shape other than the round a somewhat different velocity would be found, as it suggested for one size and kind of material in the results of Table VI.

To calculate the weight from a known velocity, let W' represent the weight in pounds of a given material having the specific gravity s , in the dry loose state of aggregation, that will flow in t seconds, through an orifice a' square feet in area, with a velocity of v feet per second, where k is the weight in pounds of one cubic foot of water. The weight in avoirdupois pounds, accordingly, is as follows:

$$W' = vta'sk \dots\dots\dots (1)$$

Taking 62.42 pounds as the weight of one cubic foot of water at 0° C., the weight W' of material of specific gravity s , having a velocity of v feet per second, that will be discharged in one second through any orifice of area a' square feet is as follows:

$$W' = 62.42 vsa' \dots\dots\dots (2)$$

Adopting the more convenient units, in which W is made the weight in pounds of material that the orifice will discharge each minute, v remains the velocity of flow in feet per second, but in which a is the area of the orifice in square inches, the following equation is obtained:

$$W = 26.008 vsa \dots\dots\dots (3)$$

For round orifices of diameter d inches, the corresponding equation, showing the weight in pounds per minute, is as follows:

$$W = 20.43 v s d^2 \dots\dots\dots (4)$$

Conclusions.—The following deductions may be based upon the results of the foregoing tests:

The uniformity of flow of sands through discharge-orifices is influenced by the dampness, fineness, and general quality of the material. The momentary irregularity of flow is perceptible to the eye in the case of orifices that are small relative to the coarseness of the material. With long periods of observation, in the case either of large or of small orifices, a smaller but persistent variability is found to exist which is not materially diminished by greatly prolonging the time. The deviations from a uniform flow draw the attention to the manner of supplying the material to the orifice, the compacting, the head, the shape and size of the supplying receptacle, and the time during which the material is permitted to remain at rest before the flow begins. Uniformity is greatest in the case of substances least compacting under pressure, and under conditions of flow that loosen the material above and near the orifice. It is favored by thorough dryness, rounded particles, and a low sand-head. Observations deviate less than one part in six hundred in the case of river sand of .01 inch diameter, under a sand-head of three inches, flowing five minutes through round orifices of $\frac{1}{4}$ inch diameter; while under the same conditions, but with angular or damp material, deviations exceed one part in fifty.

The velocity of flow under the existing conditions of gravity is governed chiefly by the size of the orifice and the size of the grains. Other important influences are the shape and surface condition of the grains and the shape of the orifice. Other conditions to be mentioned in the present summary exert a less marked influence.

The size of the grains influences the velocity of flow, causing, with the increase in size, a decrease in the velocity. This is shown in the case of river sand in Diagram I. There is here observed a maximum velocity at which the ratio of the diameter of the grains to that of the orifice ranges from 1 : 15 to 1 : 30 approximately. With finer material the velocity quickly drops

from this maximum, while with coarser the drop is seen to be gradual and, on the whole, more regular. The size of the grains is closely related to the shape and surface condition, one quality merging into another and requiring common consideration in the case of substances which require handling in practice.

The moisture content produces a retardation of the flow. The influence with increasing fineness and decreasing density becomes greater. The moisture in material which is positively dampened can alter the rate of flow many-fold, producing results out of all semblance to uniformity. As the material becomes progressively drier, the velocity of flow becomes greater and more uniform.

Angularity of the particles causes a diminution of velocity. The effect is less marked with fine material and with large orifices.

The uniformity of size of the grains is of influence upon the velocity. The velocity of a mixture of materials, with respect to the weight, approximates and slightly exceeds the mean of the velocities of the two sizes flowing separately. Thus the time occupied in the discharge of a given weight of material of mixed sizes is slightly less than that which would be required for the discharge of each sized constituent separately. This is shown in Diagram II.

The material of which the orifice is constructed is shown to modify the velocity to a small extent. Results with $\frac{1}{4}$ -inch orifices are given in Table IV.

The specific gravity of the flowing material is without relatively appreciable influence upon the velocity of flow under practical conditions. This is shown in Table III.

The sand-head exerts a barely appreciable influence upon the velocity of flow. The influence is in the direction of a decreasing velocity with increasing head. With materials capable of becoming compressed or compacted, the retarding effect of the head becomes more pronounced. A consideration of the sand-head must thus include not only the height of the column and the specific gravity of the material, but the impact in gathering above the orifice, the dampness, coherence, and the angularity.

The contour at the surface of the material above the orifice exerts a minute influence upon the velocity. Thus when the surface is allowed to sink directly above the orifice, so as to

form a pit, there is a slight increase in flow perceptible beyond that observed when the surface is level at the height corresponding to the bottom of the pit.

The shape of the receptacle supplying an orifice has but slight influence upon the velocity of flow where the bottom is flat around the orifice and the vertical column of material above the orifice remains unobstructed.

The effect of taper in orifices is an increase in flow where the enlarged opening of the orifice is presented to the descending material.

The length of discharge-orifices, or the thickness of the plate through which orifices are cut, is of scarcely appreciable effect as examined within the range of one inch.

The size of an orifice at the minimum required for an assured continuous flow must liberally exceed that found suitable for short intervals, to provide for the variability in quality of usual sands and the chance arrangement of particles in obstruction. The diameter of round orifices suitable for the steady flow of the sand materials tested ranges from five to twenty times the diameter of the particles, according with the size and quality of the material.

The horizontal, cross-sectional shape of the vertically discharging orifice influences the velocity of flow. The velocity is highest among the discharge-orifices tested having the greater ratio of area to periphery.

The area or size of the orifice affects the velocity. Thus the discharge is governed both by the area over which the given velocity is effective and by the velocity resulting from this area. It is seen in Diagram III that the velocity decreases with the decreasing diameter of the orifice, the curve showing a rapid decline near the limiting size of the orifice where the flow becomes irregular.

The differences in the surface condition of the grains, with the influence which this has upon the cohesion and the frictional coefficient, produce an important effect upon the velocity of flow. The content in moisture, the composition of the material, the hygroscopic properties, the angularity, and the uniformity of size are best judged, for purposes in practice, by the evident general quality of the material as a whole. In the case of lead shot, a material in which the influence of angularity of the

grains is eliminated, a variation of 20 per cent. or more in the velocity results from the alteration of the surface with substances imparting a high and a low coefficient of friction.

An approximate constant to express the flow in terms of the orifice area, or the coarseness of material, can be used to gain a general idea of the discharge capacity of an orifice for a given material. Under the conditions of apportionment of sand materials by orifices in practice, prediction must be considered widely approximate. Results, moreover, are liable to marked deviation from changing quality of the material. In such application, differences in the specific gravity and the sand-head are of relatively small importance. The flow is seen to be actuated by the force acting upon the material distant but few diameters of the orifice from the orifice, and is thus affected only by the condition there existing. There is little serviceable analogy between the flow of fluid substances and of sand composed of solid grains.

An expression giving an idea of the flow to be expected would be sought for certain purposes from the trend of the curves. For such approximation, in which an accuracy of some 20 to 50 per cent. is obtained, based upon the size of the round orifice and the coarseness of the material, the following formula may be suggested:

$$V = k \frac{d - cm}{\sqrt{d}}.$$

Here d is the diameter of the orifice in inches, m is the diameter of the particles in inches, V is the velocity of flow in feet per second, and k and c are constants to which are assigned respectively, in approximation, the numerical values 1 and 2.

The weight of sand discharged during each minute is correspondingly shown in the same degree of approximation by substituting the above value of V for the value v in equation (4), for round orifices, as given under *The Rate of Discharge*. From this the following equation is derived:

$$W = 20.43 s \sqrt{d^3} (d - 2m).$$

Here W is the weight of sand discharged in avoirdupois pounds per minute, s is the specific gravity of the sand in the

dry, loosely aggregated state, d is the diameter of the round orifice in inches, and m the diameter of the grains in inches.

An outline of the conclusions to be drawn from the tests described would be: (1) The increase in the velocity of flow with the increase in the diameter of the orifice; (2) the increase in the velocity of flow with the decrease in the diameter of the particles until the size of relatively fine material is reached; (3) the comparative unimportance of the variation in specific gravity of materials; (4) the relatively small influence of the variations in head; (5) the relatively small influence of the shape of the supplying reservoir; and (6) the influence of dampness and compacting qualities of the material, most marked in the fine sizes.

Cementation with Mixed Carburizing Agents. A. PORTEVIN. (*Mem. Soc. Ing. Civils de France*, lxvi, 347.)—This describes experiments on a practical scale of cementation with mixed agents,—*i.e.*, with a layer of wood charcoal of considerable thickness through which a current of carbon dioxide is passed at the temperature of cementation. The advantages of this method of cementation are described in detail.

Methyl Alcohol as a By-product in the Manufacture of Wood Cellulose. H. BERGSTRÖM. (*Papierfabrikant*, x, 697.)—Since 1908 the Billingsfors mill has been recovering methyl alcohol as a by-product from the digestion of wood by the sulphate process. In the manufacture of easy bleaching pulp, about 13 kilos. of methyl alcohol are produced per 1000 kilos. of cellulose. About 5 kilos. of this per 1000 are collected by condensing the vapors discharged at between 10 and 4 atmospheres from the digesters. This spirit is purer than ordinary wood spirit and contains 0.5 per cent. of acetone. The cost of recovering methyl alcohol amounts to 10 öere per kilo., or 12 cents per pound of absolute alcohol, and its value is 45 öere, or 54 cents per pound. More crude spirit may be obtained by condensing the vapors discharged below 4 atmospheres and those formed during evaporation of the lyes, and the refining of the raw spirit is profitable. This year five sulphate pulp factories are recovering methyl alcohol. Pine wood and spruce wood yield about the same quantity of spirit. In the digestion of wood by the Ritter-Kellner sulphite process, from 8 to 10 kilos. of methyl alcohol are formed per ton of easy bleaching cellulose, about 3 kilos. being condensed in the "gassing-off" process. If the waste lyes remaining in the digester be then distilled in a continuous column apparatus, a distillate is obtained containing methyl alcohol, acetaldehyde, acetone, oils, sulphurous acid partly combined, and small quantities of formic and acetic acids.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ABSORPTION CONSTANTS OF QUARTZ.

Paper by W. W. Coblentz.

AN accurate knowledge of the transmission of quartz, in the infra-red, is essential in order to determine spectral energy curves. Quartz has a much larger dispersion than fluorite. Unfortunately, unlike fluorite, the absorption in quartz becomes quite marked at 2μ and is practically complete beyond 3μ . However, for the spectral region from the deep ultraviolet to 1.7μ in the infra-red, quartz has the remarkable property of complete transparency for the thicknesses (3 cm.) which are ordinarily used in optical investigations. • This is illustrated in the present research, where it is shown that after eliminating the losses for reflection at the interface, quartz-air, the transmission is practically complete.

In this investigation an especially prepared cylinder of clear quartz, 50 mm. in diameter and 29.925 mm. in thickness, cut perpendicular to the optic axis was used. The faces were plane to a fraction of a wave-length of light, and they were parallel to within $1'$. The source of energy was a seasoned Nernst glower, operated on a storage battery. The rays from the glower were made parallel by means of a 50 cm. focal length silvered mirror, and from thence passed to a second mirror, 90 cm. focal length, which brought the rays to focus upon the spectrometer slit. A blackened diaphragm having an opening of about 3 by 3.5 cm. was placed in the path of parallel rays. The quartz cylinder was mounted upon a suitable stage, sliding back and forth, close to and in the rear (*i.e.*, between the diaphragm and the second mirror) of the diaphragm. The ratio of the galvanometer deflection observed when the quartz plate was over the opening in the diaphragm, to the deflection caused by the rays passing through the diaphragm without obstruction by the quartz, gave the transmission, which, of course, includes the losses by reflection from the two surfaces. Atmospheric disturbances were unusually small,

* Communicated by the Bureau.

so that the galvanometer could be read to 0.1 mm., thus producing an accuracy of several parts in one thousand instead of a few parts in one hundred, which is the usual record of radiometric work.

The true transmission of quartz is obtained by applying the well-known Fresnel formula for vitreous reflection. The radiations contributed by two reflections $(1 + \gamma^2)$ within the quartz plate are negligible in most work. If there were no errors of observation and no scattering of light, the values should be $T_0 = 1$. This is true to about two parts in 1000 for the region of transparency from 0.8μ to 1.8μ . The second column of Table I gives

TABLE I.
TRANSMISSION OF QUARTZ.

λ	T'_0 <i>t</i> = 29.925 mm.	T_0 <i>t</i> = 27.915 mm.	Absorption index. <i>K</i> —Mean value of two samples.
0.0005893	.99600	.99578	0.000,000,007,803
.0008820	.99970	.99545	0.000,000,009,153
.0011971	1.00223	.....	0.000,000,001,808
.0016132	1.00000	1.0000	0.000,000,009,567
.0017835	.99984	.99986	0.000,000,011,06
.0019518	.99665	.99768	0.000,000,021,57
.0021128	.99292	.99478	0.000,000,036,13
.0022654	.98620	.98796	0.000,000,066,96
.0024098	.97782	.97948	0.000,000,108,98
.0025458	.95020	.95552	0.000,000,238,99
.0026120	.....	.93994	0.000,000,322,64
.0026757	.91954	.92715	0.000,000,405,34
.0027392	.....	.84458	0.000,000,893,69
.0028010	.54944	.57891	0.000,002,949,58
.0029213	.099696	.08135	0.000,012,939,7
.0030373	.....	.15496	0.000,010,793,4

the transmission T'_0 on the assumption that there is perfect transmission up to and at 1.6132μ . The deviations from $T_0 = 1$ are then found to be far smaller than the average experimental errors which usually enter into such work.

The absorption index (extinction coefficient) κ is computed from the equation $A = l - e^{-a l}$, where $a = 4 \frac{\pi \kappa}{\lambda}$. Here the thickness, l , of the plate and the wave-length are in millimetres. The data are given in the last column of Table I. The absorption band of quartz occurs at 2.95μ .

The factors for eliminating the absorption in a wedge of quartz are determined from the equation

$$\frac{I_0}{I} = \frac{\log (1-A)^{B/l}}{[(1-A)^{B/l}-1] \log \varepsilon}$$

In these equations A is the absorption $(1 - T_0)$ observed in the quartz plate and l is its thickness (29.925 mm.); B is the thickness of the back of the prism (*i.e.*, the width of the face, 52 mm., which is opposite the refracting angle), and h is the vertical height of the refracting edge from the back of the prism. The observed intensity (in galvanometer deflections) is I ; and I_0 is the true intensity of the radiations emanating from the source. A further increase in the value of I_0 is, of course, necessary for loss by reflection, r , from the prism faces and for variation of reflection, γ^2 , with angle of incidence.

Table II gives the factors to be used in eliminating this absorption in a quartz prism the back face of which is 50 to 52 mm. in thickness. From this table it will be found that, for example, at 2.70μ the observed intensity must be increased by 8.8 per cent. in order to correct for the loss by absorption in the prism.

TABLE II.

TRANSMISSION—QUARTZ.

Factors for eliminating absorption in a quartz prism having a base (back face) of 50 to 52 mm. width.

λ	Factor
1.8	1.0000
1.85	1.0010
1.90	1.0019
1.95	1.0028
2.00	1.0038
2.05	1.0050
2.10	1.0062
2.15	1.0076
2.20	1.0091
2.25	1.0108
2.30	1.0132
2.35	1.0165
2.40	1.0205
2.45	1.0262
2.50	1.0335
2.55	1.0430
2.60	1.0550
2.65	1.0690
2.70	1.0880

Lack of Dock Accommodation. ANON. (*Amer. Mach.*, xxxix, No. 24, 996.)—The increase in the size of modern transatlantic liners has called attention to the lack of suitable dock accommodation, but this is being remedied on this side of the ocean. Both Canada and this country are beginning to feel their responsibilities, and dry docks to take the largest ships will soon be found on the Atlantic seaboard. The Canadian Government is planning to build at Levis, on the St. Lawrence, a dry dock of the following dimensions: length, 1160 feet; width of entrance, 120 feet; depth of sill at ordinary high water, 40 feet. It will be the largest in existence and will be divided into two sections, 660 and 500 feet long respectively. Boston is shortly to have two dry docks capable of receiving the largest boats, though these will not be quite so large as the Canadian docks. They are to cost approximately \$3,000,000, and the Cunard, International Mercantile Marine, and Hamburg-American lines are to subscribe \$50,000 a year for 20 years for their use.

Nickel as Catalyst. J. B. SENDERENS and J. ABOULENC. (*Bull. Soc. Chim.*, xi, 641.)—The temperature at which nickel oxide is reduced by hydrogen depends on the mode of preparation and treatment of the oxide used; there is also a considerable difference between the temperature at which reduction commences and that at which it is complete. Complete reduction is not effected below 300° C., but the mixture of metal and oxide thus obtained is more active than the metal prepared by total reduction at a higher temperature; the activity of reduced nickel being diminished by heating to a comparatively high temperature, although at the same time its catalytic properties become more permanent. Pyrophoric nickel, when heated in the air, furnishes an oxide which is reducible at a comparatively low temperature, and reduced nickel of impaired activity may be restored by oxidizing it and again reducing.

A New Alloy—Argental. ANON. (*Amer. Mach.*, xxxix, No. 24, 1002.)—The inventor of the "McAdamite" alloy has produced this new alloy of silver and aluminum, named Argental. It was produced as a substitute for silver, and is claimed to be superior to silver for many industrial uses. It can be cast, rolled, spun, drawn into wire, and takes a good polish, and is stronger than either silver or aluminum. It resembles silver, is not affected by nitric acid, and does not tarnish in air. As its specific gravity is only one-third that of silver, it may be used for the manufacture of tableware specialties and the like.

Quality of Steel. ANON. (*Amer. Mach.*, xxxvi, 26, 1018.)—The rapid development in the quality of steel must be credited to a great extent to the automobile and the aeroplane. Wire for aeroplane stays or guys is made from 0.025 to 0.102 inch diameter, with a tensile strength of 350,000 pounds per square inch.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, March 18, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 18, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 6.

Dr. George A. Hoadley, on behalf of the Committee on Science and the Arts, introduced Mr. George W. Loggie, treasurer of the Kinkead Manufacturing Company, Boston, Massachusetts, to whom had been awarded the Longstreth Medal of Merit for their apparatus for aligning and levelling shafting. The chairman then presented the medal to Mr. Loggie.

After the transaction of the above business a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers, President Clark and Chairman Cheyney presiding jointly.

It was announced that because of death in his family Dr. Edwin F. Northrup, who had been scheduled to speak on "The Problem of Electrical Conduction," found it impossible to be present.

Mr. H. A. Hornor, Electrical Engineer of the New York Shipbuilding Company, presented an interesting communication on "The Marine Applications of Electricity." The many and varied uses of electricity on board ship were fully described, including its applications in signalling to and from various parts of a vessel, as an adjunct in gunnery for range finding and other purposes, for lighting, heating, baking, and for communication between vessels and land. The subject was illustrated by lantern slides.

After a vote of thanks to the speaker, the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
March 4, 1914.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 4, 1914.

MR. GEORGE R. HENDERSON *in the Chair.*

The following report was presented for first reading:

No. 2596.—Hirsch's Electric Safety Lamp.

The following report was presented for reconsideration:

No. 2530.—Stumpf's Una-Flow Steam Engine. Edward Longstreth Medal of Merit. Adopted.

The following resolution, expressing the regrets of the committee on the retirement of Prof. Lewis M. Haupt, was unanimously adopted:

"The Committee on Science and the Arts of The Franklin Institute, in view of the retirement of Prof. Lewis M. Haupt from active participation in its work, unanimously resolves that the following appreciation shall be entered on the minutes of the committee and published in the JOURNAL of the Institute:

"The committee notes that Professor Haupt's membership in this body has extended almost continuously through more than thirty years (from 1883 to the present time), and makes record that throughout this period his collaboration, not only as an acknowledged authority in water and land transportation, in harbor improvements and in the broad domain of engineering generally, but also as a scientific publicist and economist, has been of the utmost value to the cause for the promotion of which this committee is organized.

"The committee has come to recognize Professor Haupt as a veteran scientist whose ripened judgment has been instructive and whose genial personality has been an inspiration to all his co-workers, and greatly regrets that his formal and active coöperation has now been withdrawn. On its own behalf and for the Institute, the committee extends to Professor Haupt a thankful acknowledgment of his many years of valuable service."

R. B. OWENS,
Secretary.

PRESENTATION OF THE EDWARD LONGSTRETH MEDAL OF MERIT TO KINKEAD MANUFACTURING COMPANY.

The Edward Longstreth Medal of Merit, awarded to Kinkead Manufacturing Company for their apparatus for aligning and levelling shafting, was presented to Mr. George W. Loggie, Treasurer of the Company, at the Stated Meeting of the Institute on Wednesday evening, March 18.

Dr. George A. Hoadley referred to the recommendation embodied in the report of the Committee on Science and the Arts, that this Medal be awarded the Company for their device in consideration of its novelty, simplicity, and efficiency. He then presented Mr. Loggie to the President, by whom he was given the Medal.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on Wednesday evening, February 11, at eight o'clock.

Mr. Louis E. Levy occupied the chair.

The minutes of the previous meeting were approved.

Oswald Schreiner, Ph.D., of the Bureau of Soils, U. S. Department of Agriculture, Washington, D. C., delivered an illustrated lecture on "The Biochemistry of Soil Fertility," in which he described the soil fertility investigations of that Bureau.

A description was given of the gradual chemical decomposition of animal and vegetable matter in the soil with the formation of a great number of organic compounds, some toxic to plant life, others exerting a highly favorable influence on plant growth. The methods of isolation of these compounds from the soil, and of testing their action, singly, in combination with each other, and with inorganic fertilizers, upon plants in the laboratory and in field experiments, were discussed. The relation of the results obtained to scientific agriculture was shown.

The paper was discussed at great length, a vote of thanks was extended to Dr. Schreiner, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, February 26, at eight o'clock.

Dr. Walton Clark occupied the chair.

The minutes of the previous meeting were approved as published.

The Chairman introduced Prof. M. E. Cooley, D.Eng., LL.D., Dean of the Department of Engineering, University of Michigan, Ann Arbor, Mich., who delivered a lecture on "The Valuation of Public Utility Properties."

The speaker emphasized the necessity of a correct knowledge on the part of the public of the fundamentals of public utilities. He said that the fullest coöperation should exist between public utility commissions of the different States, municipalities, and the Federal Government, in framing legislation and in the conduct of investigations of the relations of public utilities to the public. He outlined the many expenses entailed in promoting a public utility, which he said were but rarely considered by the public.

After discussion by members present, the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on Thursday, March 5, 1914, at 8 o'clock P.M., with Mr. E. H. Sanborn in the chair. The minutes of the previous meeting were read and approved. L. C. Jones Ph.D., of the Solvay Process Company, Syracuse, N. Y., delivered an address entitled "By-Products of Coal," in the course of which he discussed the geo-chemistry of the formation of coal deposits and described certain new coal fields. The physical and chemical changes undergone by various species of coal on heating were described, as was the influence of the temperature and the pressure on the yield of gaseous products, ammonia, ferrocyanide, and benzol hydrocarbons. The lecture was illustrated by means of lantern slides and by specimens of coals before and after heating. The paper was discussed and, on motion of Dr. Walton Clark, a vote of thanks was extended to the speaker. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.**Elections to Membership.**

(Stated Meeting, Board of Managers, March 11, 1914.)

RESIDENT.

- MR. J. STUART FREEMAN, 1429 Chestnut Street, Philadelphia.
DR. CHARLES S. HOLLANDER, 40 North Fourth Street, Philadelphia.
MR. JOSEPH M. JAMESON, Girard College, Philadelphia.
MR. CHARLES W. THOMAS, Silica Stone Works, Frazer, Pennsylvania.

NON-RESIDENT.

- MR. HERBERT A. BURSON, Canadian Crocker-Wheeler Company, St. Catharines, Ontario, Canada.
MR. MALCOLM ELLIS, Ellis Adding Typewriter Company, Newark, New Jersey.

Changes of Address.

- MR. FRANCIS H. ADLER, 3400 Walnut Street, Philadelphia.
MR. FRANCIS T. CHAMBERS, Esquire, 712 Walnut Street, Philadelphia.
MR. GEORGE R. HALL, Hotel Grand, 31st and Broadway, New York City, New York.
MR. T. CHALKLEY HATTON, City Hall, Milwaukee, Wisconsin.
MR. WILLIAM R. HUTTINGER, 58 West Stratford Avenue, Lansdowne, Pennsylvania.

NECROLOGY.

Dr. Edwin James Houston was born at Alexandria, Va., in 1847. He was educated at the Central High School, Philadelphia, and was graduated Bachelor of Arts in 1864; he received his Master's degree from the school later, and subsequently the honorary degree of Doctor of Philosophy from Princeton University.

For twenty-six years Dr. Houston was a member of the faculty of the Central High School, occupying the chair of Physical Geography and Chemistry. Later he became associated with Dr. A. E. Kennelly under the firm name Houston and Kennelly, consulting engineers.

He was perhaps best known as one of the inventors of the Thomson-Houston system of arc lighting and as a writer of many books on electrical subjects.

Dr. Houston was elected to life membership in The Franklin Institute in 1868. He was a member of a number of committees, including special electrical committees and committees on lectures and meetings. He was chief electrician of the International Electrical Exhibition held in Philadelphia in 1884 under the auspices of the Institute.

He was Emeritus Professor of Physics of The Franklin Institute, a member of the 1884 U. S. Electrical Commission, the American Philosophical Society, the American Institute of Mining Engineers, and was twice President of the American Institute of Electrical Engineers.



EDWIN JAMES HOUSTON
1847-1913

George Westinghouse was born at Central Bridge, N. Y., in 1846. He attended the public high schools at Schenectady, and at the age of seventeen enlisted in the Union Army. In 1864 he was appointed Third Assistant Engineer, U. S. Navy, and was honorably discharged in the following year. He then entered Union College, where he remained until the close of his sophomore year. He had early exhibited an inventive capacity, having at the age of fifteen developed a rotary engine. In 1865 he invented a device for replacing derailed railroad cars upon their tracks, and three years later he patented his first invention of the air-brake.

The Westinghouse Air Brake Company was formed in July, 1870, and in the same year Mr. Westinghouse went to England to introduce the air-brake there. He spent seven years in that country between 1871 and 1882, and succeeded in overcoming the difficulties incident to the application of his invention to European railroad practice. In the meantime, he invented the "automatic" feature of the brake, which removed the danger from the parting of trains on steep grades, accomplished by the incorporation of the "triple valve." The automatic and quick action brakes are regarded by experts as surpassing the original brake in ingenuity, and, in the present-day air-brake practice, these inventions are utilized as essential embodiments.

In 1880 Mr. Westinghouse became interested in the operation of railway signals and switches by compressed air, and the system later patented by him was successfully introduced at many of the largest depots in this country.

The Westinghouse Electric Company was formed in 1886 as a result of Mr. Westinghouse's interest in the manufacture of electric lamps and lighting apparatus; the business of this corporation rapidly developed, and it absorbed other properties and was reorganized into the Westinghouse Electric and Manufacturing Company in 1891, the concern now employing over twenty-two thousand people. Mr. Westinghouse secured for this company the contract for the electrical equipment of the World's Fair in 1892, and for the generators at Niagara Falls in the following year.

The question of the steam turbine and its applications was investigated by Mr. Westinghouse, and he secured the patent rights of Chas. A. Parsons, of England, in 1897-98. This development of a new prime mover soon led the inventor to consider the use of the turbine as a prime mover for ships, and Mr. Westinghouse developed and brought out one of the most ingenious devices of modern mechanical engineering—the gear for reducing the inherently high speed of a turbine to the slow speed of a ship propeller or direct current dynamo. He accomplished this work in collaboration with the late Admiral Geo. W. Melville, U. S. N., and John H. MacAlpine. Within the last few years he also occupied himself with the development of an air spring for automobiles and motor trucks, which rapidly came into favor.

Mr. Westinghouse rendered an invaluable service to electrical development when, in spite of much opposition, he remained steadfast in his belief that the alternating current system of high-tension transmission would make distant electrical distribution possible.

A struggle almost identical with that of the earlier fight for alternating-

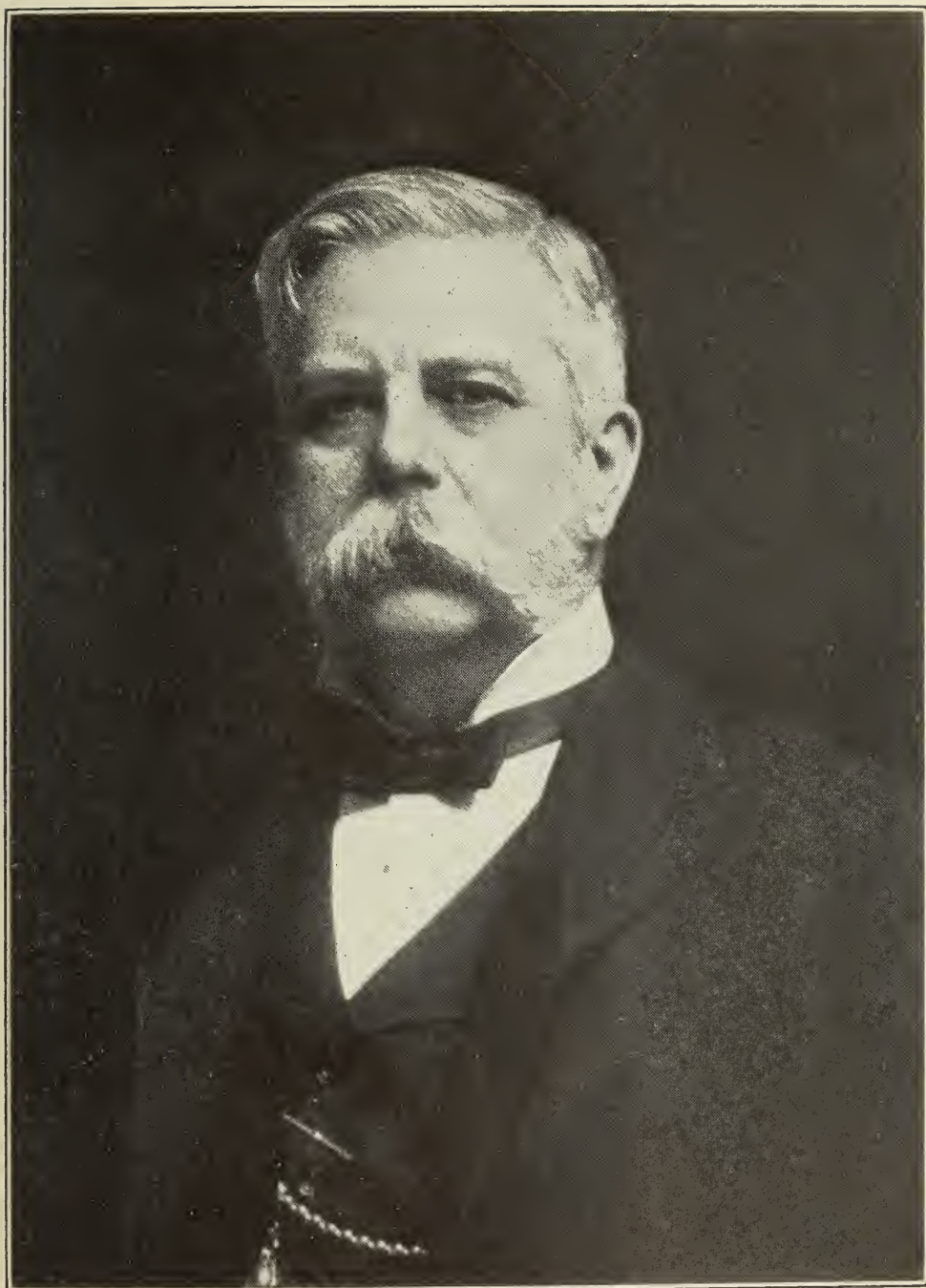
current transmission was the recent introduction of alternating-current traction by means of the single-phase motor, which the Westinghouse Electric and Manufacturing Company has now brought into reality in the case of a number of traction lines, railroad terminals and tunnels. In spite of the same competition, Mr. Westinghouse made a step in electric railway practice which the electrical world was, in like manner, quick to follow.

Originating with one of the most important inventions connected with railways, the various Westinghouse industries have grown and have been largely identified with railway progress, and it is interesting to note that this progress has represented increased security of life, increased capacity of the railway, and reduced cost of operation.

As with his first invention, the air-brake, the different apparatus has been developed to answer actual needs, in some cases acknowledged generally, and in others foreseen by him with remarkable precision. When the apparatus had passed the experimental state and was ready for commercial exploitations, he established factories which are themselves models, and which show the same anticipation of future development. Not only are the buildings handsome and well equipped with the best tools, but the comfort of the employees has been considered in every respect. It is noteworthy that the fifty-four-hour week was started in the Air Brake Works in 1869, and has been adopted in all the other plants as they have been established.

Mr. Westinghouse received many honorable distinctions for his achievements and in recognition of the services he rendered the various branches of engineering. His alma mater, Union College of Schenectady, conferred upon him the degree of Doctor of Philosophy in 1890. He was decorated with the order of the Legion of Honor, with the order of the Royal Crown of Italy, and with the order of Leopold of Belgium. He was the second recipient of the John Fritz medal. He received the honorary degree of Doctor of Engineering from the Koenigliche Technische Hochschule of Berlin, Germany, in 1906. He was an honorary member of the American Society of Mechanical Engineers, of which body he was president in 1910. He was one of the two honorary members of the American Association for the Advancement of Science. He was an honorary member of the National Electric Light Association of America. He was awarded the John Scott Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute of the State of Pennsylvania for his inventions of the air-brake in 1874. He received the Edison gold medal for meritorious achievements in the alternating-current system of electrical distribution. In December, 1913, he was presented, in New York City, with the Grashof Medal awarded him by the Verein Deutscher Ingenieure, which society recognized him as the greatest American engineer.

Mr. Westinghouse was connected with a large number of industries both at home and abroad. He was President and Director of Westinghouse Air Brake Co.; Westinghouse Machine Co.; Nernst Lamp Company; The Union Switch & Signal Co.; Société Anonyme Westinghouse, Paris; Cooper Hewitt Electric Co.; Pittsburgh Meter Co.; Société Italiana Westinghouse, Italy; The East Pittsburgh Improvement Co.; the Westinghouse Brake Co., Ltd., London; Westinghouse Cooper Hewitt Company, London;



GEORGE WESTINGHOUSE, JR.
1846-1914

Westinghouse Friction Draft Gear Co.; Westinghouse Metal Filament Lamp Co., Ltd., London. He was also Chairman of the Board of Directors of Westinghouse Electric Co., Ltd., London; and Director, Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.; the Traction & Power Securities Co.; Westinghouse Metallfaden Glühlampenfabrik, Vienna. He became a life member of the Institute on July 3, 1873.

Mr. George Thomson was born in Philadelphia November 25, 1841. He was educated in the schools of his native city and about 1861 with Amos Westcott founded the firm of Westcott & Thomson, who were among the first in Philadelphia to apply electrotyping to commercial purposes. Mr. Thomson took an active interest in politics and was a member of numerous fraternal associations. He died January 28, 1914.

Mr. Charles H. Cramp, Beach and Ball Streets, Philadelphia.

Mr. H. Van Meerten, Buitenzorg, Java.

Dr. Thomas Wistar, East Penn Street, Philadelphia.

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BOOK NOTICES.

INDUSTRIAL ORGANIC ANALYSIS. By Paul S. Arup. Published by P. Blakiston's Son & Company, Philadelphia. 340 pages, 18 x 12 cm. Price, \$2.25.

The purpose of this little manual is to supplement the purely scientific training of the chemical student by some training in practical methods. The

subjects handled are fuels, coal tar, oils and fats, soap, petroleum, and food products. Each chapter ends with an excellent bibliography. In most cases the author has wisely adopted the policy of giving only one method for each determination. A multiplicity of methods merely bewilders the beginner, since he has not as yet had the experience necessary to make an intelligent choice. The author of his text-book should do the selecting.

In the present book the methods are well chosen and the descriptions, while concise, are sufficiently full and exact. There is an excellent index.

ROBERT H. BRADBURY.

QUANTITATIVE ANALYSIS. By Frank Clowes and J. Bernard Coleman. Tenth edition. Published by P. Blakiston's Son & Company, Philadelphia. 577 pages, 22 x 14 cm. Price, \$3.50.

The ninth edition of this standard text was reviewed in this JOURNAL about two years ago. The size of the book remains almost unchanged from the ninth edition, only twelve pages having been added. Nevertheless, some interesting new matter appears. Among the more noteworthy additions are methods for the analysis of commercial aluminum and bauxite, for the estimation of titanium in iron ores, for the determination of phosphorus and manganese in iron and steel, of moisture in coal, of foreign fats in butter, and a description of a new drying oven. This new material is collected into an appendix.

In the analysis of aluminum the fact that the commercial metal invariably contains *gallium* is not mentioned. However, the percentage of gallium is very small, and its determination would hardly be a task for the beginner.

The new method for phosphorus consists in dissolving the yellow phosphomolybdate precipitate in ammonia, acidifying with hydrochloric acid, and precipitating with a solution of lead acetate. The lead molybdate is ignited and weighed and the phosphorus calculated. In other words, the method is merely an application to phosphorus of Chatard's method for determination of molybdic acid.

The student who works the method from the description on page 550 would in all probability ignite his lead molybdate with the filter in a covered platinum crucible. Probably the author intends him to use a Gooch crucible, but there is nothing to indicate the fact. The reviewer has no experience of the method, but he confesses to cherishing considerable scepticism as to whether it possesses any advantages over the method at present in use for the estimation of phosphorus.

This is probably the best manual to put into the hands of the student beginning quantitative work. The usefulness of the book is greatly increased by an elaborate system of cross-references.

ROBERT H. BRADBURY.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. Fourth edition, vol. viii. Edited by W. A. Davis and S. S. Sadtler. Published by P. Blakiston's Son & Company, Philadelphia. 696 pages, 23 x 14.5 cm. Price, \$5.

The fourth edition of this standard work is now complete. The chief

subjects treated in the eighth and final volume are Enzymes (Armstrong), Proteins (Schryver), Proteins of Plants (Armstrong), Milk (Leffmann), Meat (Richardson), Albuminoids (Alexander), Fibroids and Artificial Silk (Dreaper).

ROBERT H. BRADBURY.

BLOXAM'S CHEMISTRY. Tenth edition, rewritten and revised by Arthur G. Bloxam and S. Judd Lewis. Published by P. Blakiston's Son & Company, Philadelphia. 878 pages, 24 x 15 cm. Price, \$5.50.

When the first edition of Bloxam was issued, in 1867, it gave, in little more than six hundred pages, a compendious account of the chemical science of the time. At present, just about half a century later, the task of adequately treating all phases of the subject, technical and scientific, organic and inorganic, in a single volume wears a very different aspect. It is somewhat difficult to see what advantages a single encyclopædic work possesses, compared with several smaller specialized books covering the same ground. Nevertheless, the marked success of the two recent volumes by Ettore Molinari indicates that there is a considerable demand for comprehensive treatment of this kind.

The authors of the present book are to be congratulated on having performed a laborious piece of work in a very creditable way. The book presents an enormous mass of information on all branches of chemistry. It has been revised and modernized with great care, and everything which may fairly be supposed to fall in its scope is to be found in it. The index—a most important feature in a comprehensive volume of this kind—is unusually complete, covering more than fifty pages in double column.

ROBERT H. BRADBURY.

DIE ENTDECKUNG DES RADIUMS. Von Mme. P. Curie. Octavo, 28 pages, with 5 illustrations. Leipzig: Akademische Verlagsgesellschaft m. b. H. Price, 1.50 marks.

This is the authorized German edition of the address delivered by the illustrious discoverer on receiving the Nobel Prize for Chemistry in 1911. It narrates in charmingly simple and clear language the story of the discovery and investigation of the radio-active substances. While of necessity this account is largely concerned with the results of her work on radium and polonium, for which the prize was awarded her, the author, in a most delightful spirit of fairness and generosity, accords due credit to the other great investigators in the field of radio-activity. Particularly pleasing in this respect are her references to the achievements of Henri Becquerel and Ernest Rutherford, and to the part which her late and lamented husband, Pierre Curie, has had in the discovery of radium and polonium. It is impossible, after reading this pamphlet, to conceive of a more deserving tribute to a great scientist than the award of the Nobel Prize in chemistry to Mme. Pierre Curie.

H. F. KELLER.

LETZTE GEDANKEN. Von Henri Poincaré. Octavo, 261 pages. Leipzig: Akademische Verlagsgesellschaft, m. b. H., 1913.

As the title indicates, this is a posthumous publication from the pen of the great mathematician and philosopher. It contains nine essays and addresses on a great variety of topics, but in every instance discussing with the author's well-known breadth of vision and lucidity of presentation some scientific or ethical problem of fundamental importance. A mere glance at the headings suffices to indicate the character of this remarkable book; they are as follows: Are the Laws of Nature Invariable?; Space and Time; Why Space has Three Dimensions; The Logic of the Infinite; Mathematics and Logic; The Hypothesis of Quanta; Matter and Universal Ether; Morals and Science; and The Universality of Ethics.

In the warmly sympathetic preface which Ostwald has written for this excellent German translation of Poincaré's book he points out that the author is a typically modern investigator "who cannot acquire knowledge or occupy himself with new conceptions without engaging in creative labor in the new field thus opened up to him."

H. F. KELLER.

DER WERDEGANG EINER WISSENSCHAFT: Sieben gemeinverständliche Vorträge aus der Geschichte der Chemie von William Ostwald. Second edition. Leipzig: Akademische Verlagsgesellschaft m. b. H. Small 8vo, 308 pages and index. Price, 6.60 marks.

This is a compact summary of salient features in the history of chemistry, written so as to be useful to those not fully trained in the science. It suggests somewhat Würtz's "History of the Atomic Theory," but does not show the chauvinism of that work, which boldly and unjustly starts off with the declaration "Chemistry is a French science." Ostwald's book is in part a report of his lectures about eight years ago at the Massachusetts Institute of Technology and Columbia University, but, as might be expected, material alterations and additions have been made in reducing these to the printed form. The seven subjects are: The Elements; Combining Weights and Atoms; The Laws of Gases and the Molecular Theory; Isomerism and Structure; Electrochemistry; Affinity; Chemical Dynamics.

It is unnecessary to say that we have here presented in attractive literary form an accurate synopsis of these several important phases of the development of chemistry. The first lecture devotes some space to the very earliest history, taking, as usual, Thales as the first who treated of the manifold phenomena of nature as explicable on material principles. He regarded water as the primordial material—at least taught that all existing matter is derived from the transformation of water. Ostwald points out that in Thales's philosophy are to be found two principles that are still dominant in modern science: The doctrine that the present condition of matter is the result of change from a former condition—things have not always been as they are—and that the manifold forms of matter are referable to a limited number of original substances. The first doctrine dominates biology; the second the abiologic sciences, chemistry and physics.

By many scientists Ostwald is admired, not only for his work in research and his capacity for presenting the results of his studies in a popular form, as well as in the technical language of highly-developed science, but also

for his aggressive liberalism, and his fearless association with those who are appealing for a scientific interpretation of life. The redeeming quality of Saxon humor is not lacking, as the following quotation will show:

"Liebig, der sich durch seine in der Dachkammer der Apotheke, in der er Lehrling war, ausgeführten Arbeiten über das Knallquecksilber glücklich aus der Apotheke heraus, aber in die Aufmerksamkeit einflussreicher Personen hineinexplodiert hatte, war nach Paris gegangen." Then follows an account of the independent discovery by Liebig and Wöhler of the isomeric cyanic acids, the intervention of Berzelius with his skilful generalization, and the establishment of a lifelong friendship between the two discoverers. The human note that is so frequently apparent in the book gives it special charm.

HENRY LEFFMANN.

DAS WERDEN DER WELTEN. Svante Arrhenius. Leipzig: Akademische Verlagsgesellschaft m. b. H. 8vo, 224 pages and index. Illustrated. Price, 5 marks.

When Arrhenius asks to be heard, the scientific world must "stop, look, and listen." The volume in hand is the German translation of his well-known work, an excellent product of the printer's art and an interesting product of the speculative spirit of a great scientist. The first chapters are devoted to terrestrial and celestial phenomena, the earth being especially studied in reference to the catastrophic changes, earthquakes and volcanic eruptions. Solar phenomena are then discussed, followed by studies of star clusters and nebulae. A special chapter is given to pressure of light.

The most interesting chapter is the last, "On the Extension of Life in Space." In this the author sets forth his theory of the influence of light-pressure in driving minute spores to the different parts of space and the possibility of minute particles of cosmic dust serving as a sort of make-weight for these germs. He assumes a very abundant distribution and a comparatively small proportion of cases in which the germs light upon fertile places. One is reminded of the Parable of the Sower.

It is a disappointment that no suggestion is made in regard to the origin of life. The theory is offered only to account for the distribution of it, from some point of origin. A brief allusion is made to the suggestion that other elements of the carbon group may enter into protoplasmic constituents and give rise to protoplasm with special properties, but this speculation is rejected as very improbable.

Notice is made of some of the theories of spontaneous generation, but these also are not given any standing. It would have been very interesting to have Arrhenius's views on the relation of enzymes and colloids to vital phenomena, and some speculations as to the manner in which non-living matter might acquire vital character. Most of the so-called instances of spontaneous generation are unacceptable, because they claim the development of well-differentiated organisms. If spontaneous generation is now taking place, it is most likely to be the conversion of some complex mixture of nitrogenous bodies into a structureless and nearly quiescent mass. Long periods of evolution will probably be needed for the development of even a slightly differentiated organism.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Mechanical Laboratory Methods.—The testing of instruments and machines in the mechanical engineering laboratory and in practice, by Julian C. Smallwood, M. E., Associate Professor of Experimental Engineering, Syracuse University. 333 pages, illustrations, 12mo. New York, D. Van Nostrand Co., 1914. Price, in leather, \$2.50.

Fabrikation und Eigenschaften der Metalldrahtlampen, von Dr. phil. N. L. Müller. 192 pages, illustrations, 8vo. Halle (Saale), Wilhelm Knapp. 1914. Price, in paper, 8.60 marks.

Théorie mathématique de l'Echelle musicale par Alphonse Vaucher. 67 pages, tables, 8vo. Paris, Gauthier-Villars, 1913. Price, in paper, 2.25 francs.

Canada Department of Mines, Mines Branch: Annual Report on the Mineral Production of Canada during the Calendar Year 1912 by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 339 pages, 8vo. Ottawa, Government Printing Bureau, 1914.

Providence City Engineer, Annual Report for the Year 1912. 84 pages, maps, tables, 8vo. Providence, R. I., City Printers, no date.

American Telephone and Telegraph Company, Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1913. 68 pages, 8vo. New York, 1914.

Mellon Institute of Industrial Research and School of Specific Industries: Smoke Investigation, Bulletin No. 6. Papers on the Effect of Smoke on Building Materials. Edited by Raymond C. Benner, Ph.D. 58 pages, 8vo. Pittsburgh, Pa., University of Pittsburgh, 1913.

U. S. Department of Agriculture, Bulletin No. 14, Professional Paper, The Migratory Habit of Housefly Larvæ as Indicating a Favorable Remedial Measure. An Account of Progress, by Robert H. Hutchison, Scientific Assistant. 11 pages, 8vo. Washington, Government Printing Office, 1914.

United States Bureau of Mines: Report of the Director for the Fiscal Year ended June 30, 1913. 118 pages, map, 8vo. Bulletin 58, Fuel-briquetting Investigations, July, 1904, to July, 1912, by C. L. Wright. 277 pages, illustrations, 8vo. Bulletin 60, Hydraulic Mine Filling, Its Use in the Pennsylvania Anthracite Fields. A Preliminary Report, by Charles Enzian. 77 pages, illustrations, 8vo. Technical Paper 58, The Action of Acid Mine Water on the Insulation of Electric Conductors. A Preliminary Report, by H. H. Clark and L. C. Ilsley. 26 pages, illustrations, 8vo. Technical Paper 66, Mud-laden Fluid Applied to Well Drilling, by J. A. Pollard and A. G. Heggem. 21 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

Decomposition of Ytterbium into its Elements. C. AUER VON WELSBACH. (*Monatsh. Chem.*, xxxiv, 1713.)—By the fractionation of ytterbium the author isolated and purified the compounds of two constituent elements, cassiopeium, Cp, atomic weight = 175, and aldebaranum, Ad, atomic weight = 173. From the original 500 grammes of ytterbium oxide there were obtained about 48 grammes of cassiopeium oxide and over 200 grammes of aldebaranum oxide.

CURRENT TOPICS

Preparation of Metallic Tungsten. G. ERHARD. (*Metallurgie*, ix, 441.)—This paper discusses the various methods of obtaining metallic tungsten, and the conclusion is reached that the preparation of tungstic acid is the best intermediate stage. The purified sodium tungstate, obtained by fusion of the ore with 60 per cent. sodium carbonate, was treated with hydrochloric acid containing 6 per cent. of nitric acid, and the tungstic acid thoroughly washed to remove alkaline salts. After completely drying, 100 kilos. of tungstic acid were mixed with 14.1 kilos. of pure charcoal and 2 kilos. of rosin, and heated to 1400° C. in a crucible the lid of which was carefully luted. The agglomerated metal was then finely ground and elutriated in the usual way, yielding a product containing 96.5 per cent. of pure metal.

Melting-points of Commercial Brasses and Bronzes. ANON. (*Amer. Mach.*, xxxix, No. 24, 984.)—As the result of tests made under the direction of the United States Bureau of Mines, the following table of the melting-points of commercial brasses and bronzes has been summarized:

Alloy.	Approximate Composition.				Melting-point.	
	Copper.	Zinc.	Tin.	Lead.	C.°	F.°
Gun-metal	88	2	10	..	995	1825
Leaded gun-metal	85½	2	9½	3	980	1795
Red brass	85	5	5	5	970	1780
Low-grade red brass	82	10	3	5	980	1795
Leaded bronze	80	..	10	10	945	1735
Bronze with zinc	85	5	10	..	980	1795
Half-yellow, half-red	75	20	2	3	920	1690
Cast yellow brass	67	31	..	2	895	1645
Naval brass	61½	37	1½	..	855	1570
Manganese bronze .....	..	..	..	..	870	1600

The melting-point given is the “liquidus,” or point where the alloy is completely molten. The tests are described in detail in Technical Paper No. 60.

Two New Types of Balance for Determination of Density. M. VON SCHWARZ. (*Centr. Min. Geol.*, 1913, 565.)—One end of the balance arm carries two pans, the lower immersed in water as usual, the other moving over a graduated scale. The weight in air and loss in water can then be read off directly in the same units, and the density calculated. Tables show very satisfactory results obtained with the two models. One model takes only 0.5 gramme of material, while the other model takes up to 100 grammes.

Uses of Tantalum. ANON. (*Amer. Mach.*, xxxix, No. 20, 998.)—In the *Chemiker Zeitung* some uses of tantalum are pointed out. Below 200° C. the metal is not attacked by air or oxygen, nor by acids, except concentrated hydrofluoric acid. It is not attacked by aqua regia, nor by aqueous solutions of alkalies, but is attacked by fused alkalies. It is a good substitute for platinum electrodes when used as cathodes. If used as an anode it rapidly oxidizes, which necessitates a thin electrolytic coat of platinum. It has a peculiar advantage for the electrolytic analysis of metals, as the deposit can be removed by solution in acids.

Influence of Different Metals on the Thermo-electric Properties of Iron-carbon Alloys. EUGÈNE DUPUY and A. PORTEVIN. (*Mon. Sci.*, iv, No. 865, 55.)—If, for each series of alloys with the same content of carbon, curves are constructed representing the variation of the mean thermo-electric power as a function of their content of added metal, it is concluded that nearly always tempering decreases the thermo-electric power, the differences between the results obtained for the alloys received and tempered being very small for those alloys which contain a considerable proportion of chromium or tungsten. The shape of the curve indicates that manganese, silicon, and aluminum produce solid solutions within the limits of the alloys which were examined. Metals such as chromium, tungsten, and molybdenum give a curve which at first takes a sharp drop, indicating a solid solution, then a rise, which seems to indicate the saturation of this solid solution.

Alloy of Cobalt and Tin. ANON. (*Amer. Mach.*, xxxix, No. 24, 978.)—The official chemist of the American Institute of Metals reports that an alloy of about 40 per cent. cobalt and 60 per cent. of tin is especially resistant to acids, but owing to its brittleness it has little commercial value. Experiments, however, show that admixtures of this alloy with other metals, such as copper, produce a series of alloys which can be turned, forged, and machined and still have a high degree of chemical resistance.

Metal Sledges at the South Pole. ANON. (*Metal Ind.*, xii, No. 1, 5.)—The daily press states that Sir Ernest Shackleton will use a new sledge in his next trip to the South Pole, which will be constructed entirely of metal. This metal is reported to be a steel composition, the make-up of which is a secret, but that the metal is extremely light and has great tensile strength. In view of these facts it is pretty safe to hazard a guess that the metal in question is not a steel composition but an aluminum alloy of the nature of magnalium or duralumin. It is claimed that by the use of this metal the weight of the sledge can be reduced 60 pounds, and this means a saving of 600 pounds weight on the ice, or 20 days' food for an ice party.

Application of Electricity and Radio-activity to Agriculture.

T. THORNE BAKER. (*J. Roy. Soc. Arts*, lxii, 70.)—An account of the application of high-tension electric currents to the land by means of overhead wires for the purpose of increasing the yield of crops. It is stated that Lodge-Newman plants have been recently supplied to the Departments of Agriculture of the United States and of Egypt for experimental purposes: for 25 to 30 acres the capital outlay is \$1000, but only \$1500 for double the area. Experimental work has also been done on the effect of radio-activity, the waste material from the manufacture of radium being used, mixed with ordinary soil. Good results were obtained by mixing one part of radio-active material (2 milligrammes radium per ton) with ten of soil; with considerably larger quantities the yield was diminished and growth retarded. Some crops were benefited to a much greater degree than others: good results have been obtained with radishes and wheat, but much less marked improvement with cress; in the case of radishes the sugar content was markedly increased. It is stated that owing to the successful development of the processes of Kent-Smith and Rolfe and of Sommer comparatively poor residues from carnotite could be treated profitably for the extraction of radium, and that the supply of radium in the near future on a comparatively large scale was assured. The cost of the radio-active treatment of the soil would be about \$2.50 to \$3.75 per acre.

Hydrocarbons of Utah. C. BARDWELL, B. A. BERRYMAN, T. B.

BRIGHTON and K. D. KUHRE. (*J. Ind. Eng. Chem.*, v, 973.)—The mineral hydrocarbons which occur most abundantly in Utah are gilsonite, tabbyite, wurtzilite, ozokerite, and rock asphaltum. Then follows a brief description of the chief deposits and a review of the literature. Some of the uses of the minerals are as follows: *Gilsonite* (of which 50,000 tons were produced in 1912): Used for the paving industry, electrical insulators, roofing materials, waterproofing pipes and aqueducts, preventing corrosion of the iron plates of ships' bottoms, coating wire fencing, sea-walls, poles, etc., lining tanks for chemicals, paints for smoke-stacks, lubricant for heavy machinery, rubber substitute, binder for briquettes. *Tabbyite*: Compositions for rubber floor mats, rubber paints and roofing materials, filler for rubber mixings for tires, etc. *Wurtzilite* (of which 1000 tons per annum are produced): Varnishes, roofing compositions, etc. *Ozokerite*: Electrical insulators, altar candles, substitute for beeswax, ointments and the like, waterproofing mixtures, wax dolls, telephone receivers, phonograph records, polishes, electroplating, crayons, sealing wax. *Rock asphaltum*: Paving industry. The results of an experimental investigation of the mineral hydrocarbons mentioned are given, chiefly in tables, one of which shows the solubility of the different materials in various solvents, together with the corresponding figures for refined Trinidad pitch and Bermudez asphaltum.

A Wood that Never Rots. ANON. (*Sci. Amer. Suppl.*, lxxvi, No. 1978, 347.)—Engineers and others are annoyed by the rotting of railway sleepers, of piles, and of wood used to support galleries and in the building of ships, etc. Engineers, chemists, physicists, biologists, doctors, who for the construction of diverse apparatus, may need a wood possessing a maximum resistance to the causes of destruction, particularly humidity, are interested in this important question of the unputrescibility of wood. The ideal would be to find a wood able to resist putrefaction naturally. It appears from recent researches that the wood of the mangrove tree may be considered as absolutely unputrescible. Numerous samples of mangrove wood (*Rhizophora racemosa*) sent from French Guiana were, in 1909, placed at Collonges (Côte-d'Or) in a soaking pit in the depot of sleepers of the Paris-Lyons-Mediterranean Railway Company. These samples were surrounded with all the elements capable of producing the decomposition and rotting of the wood in the minimum of time. In spite of this the samples still remain in an excellent condition and show no signs of alteration. Why has the mangrove resisted decomposition and whence the particular and excellent qualities of this too little known wood? The grain of the mangrove is very close; hence it opposes a barrier to the invasion of water. The density of mangrove is about 110, that of oak is 70, and that of fir is 40. Moreover, mangrove wood has an amount of tannin quite sufficient to prevent the attack of insects and the multiplication of germs, damp, mould, and all the various micro-organisms which constitute the flora of the woods of different climates. The wood of the mangrove is marvellously resistant to flexion; its resistance is double that of oak, quadruple that of fir; nevertheless it is not at all brittle. To crushing, either at the end or across the fibres, it offers a resistance double that of oak and three times that of fir. It resists all attempts at twisting far better than either oak or fir, and is superior to them in suppleness. It is easily worked, and is as easily sawn as oak. It may, therefore, be concluded that mangrove wood merits employment on a large scale for numerous and varied purposes. It might be used for posts of electric lines on account of its unputrescibility, its resistance, and its suppleness. It is valuable for sleepers of narrow railways for its resistance to putrefaction and to crushing. It could be advantageously used for the special woodwork of mines. There is always good use for a wood that never rots.

Zirconium Hypophosphite, a Photo-sensitive Salt. O. HAUSER and H. HERZFELD. (*Z. Anorg. Chem.*, lxxxiv, 92.)—The hypophosphite is obtained by adding hypophosphorous acid to zirconium nitrate. The amorphous precipitate first formed redissolves in excess of the acid, and is precipitated by excess of alcohol as a colorless, crystalline precipitate, which, when dried over calcium chloride, has the composition $\text{Zr}(\text{H}_2\text{PO}_3)_4$. In direct sunlight the hypophosphite becomes deep violet. Microscopic examination of the colored crystals shows no evidence of decomposition.

The Tin-Plate Industry. (*Consular Report.*)—A report was recently presented to the British Tin-Plate Association on working conditions in Germany and Russia as compared with those in South Wales. The report was, in substance, as follows:

In Wales, 4 men per mill are employed—roller, doubler, furnace men, and behinder; in Germany, 5, the additional man being a furnace man's helper; in Russia, 7, the two additions being a behinder's helper and a bar dragger. In Wales the average output per 8 hours is 45 boxes of light plates 28 by 20 and 30 by 21 inches, as compared with only 42 in Germany, where there is a larger force per mill; in both countries the production sometimes reaches 60 to 70 boxes. The Russian mills have an average output of 95 to 100 boxes and an occasional output of 110 to 130 boxes. Their capacity is due to their large mill force and to the fact that the mills have three furnaces, one for heating the iron, and the other two in charge of the furnace man and his assistant, respectively. The German and Welsh mills have only two furnaces.

Radium Fixes on the Skeleton. ANON. (*Sci. Amer. Sup.*, lxxvi, No. 1978, 343.)—M. Domenici and M. and Mme. Laborde have injected into animals radium salts in a soluble state, and have searched the place of fixation. Fragments of bone tissue have appeared constantly radio-active during the experiments; and the experimenters have tried to make a precise determination of the quantities of radium fixed by the skeleton, the muscles, the viscera, and the skin respectively. A rabbit was killed thirty-three days after an intravenous injection of 0.06 milligramme of pure radium associated with an equal quantity of radium bromide. The skeleton, the muscles, the viscera, and the skin were then burned separately. The ashes showed that the radium was fixed on the skeleton rather than on the other parts of the organism, where it is found in only very feeble quantities. In their communication to the Biological Society, MM. Domenici and Laborde conclude that it is very probable that the ingestion of radium salts would have the same effect. Considering the well-known affinity of the skeleton for calcium and strontium salts introduced into the organism, it is quite probable that radium salts would also be fixed on the skeleton.

Electrical Properties of Copper-tin Alloys. R. LEDOUX. (*Comptes Rend.*, clv, 35.)—The author determines and plots curves to represent: (1) the electrical resistance, (2) the temperature coefficient of resistance between 0° and 100° C., (3) the thermo-electric power against lead, and (4) the temperature coefficient of the thermo-electric power, in each case, for alloys with varying percentages of copper and tin. Practically all the measurements indicate the compound Cu_3Sn , while several of the curves indicate the existence of a compound with the formula Cu_4Sn .

Pressure of Light Measured by Use of Thin Foil. G. D. WEST. (*Phys. Soc. Proc.*, xxv, 324.)—The pressure of the radiation emitted by a carbon filament lamp at a distance of a few centimetres is sufficient to cause a microscopically measurable deflection of the end of a suspended strip of gold or aluminum foil, and by this means the radiation pressure can be calculated if the weight of the strip is known. The results agree to within about 10 per cent. with the energy density of radiation as measured by the initial rise of temperature of a copper plate exposed to the radiation. The best results are obtained by working in an atmosphere of hydrogen, at 1 cm. to 2 cm. pressure, but good results are obtained with hydrogen at atmospheric pressure. Air at 1 cm. to 2 cm. pressure also gives good results. The method involves no laborious adjustments, and the apparatus is not seriously affected by vibration.

A New Element in the Atmosphere. F. W. ASTON. (*Eng.*, xcvi, 423.)—In his studies on the positive rays, J. J. Thomson obtained indications of the presence in the air of a body of atomic weight about 22 and giving a line next to neon, atomic weight 20. On continuing this work the conclusion is reached that atmospheric neon is a mixture of two gases which are identical in all their properties except their atomic weights, which are respectively 19.9 and 22.1. By 3000 fractionations of the gas, or, better, by using the diffusion method in conjunction with a new quartz-disc density balance in which 0.5 c.c. of the gas is weighed against oxygen, it is found that ordinary neon contains about 12.5 per cent. of the heavier gas, which does not appear to be a compound. The spectra of the two gases are apparently identical.

Neutralization of Chromic Acid. L. MARGAILLAN. (*Comptes Rendus*, clvii, 994.)—The progressive neutralization of chromic acid by sodium hydroxide was followed by the electrometer method, using an electrode of platinum saturated with hydrogen. The e.m.f. curve was interrupted by two almost vertical portions (instead of one, as with sulphuric acid), corresponding respectively to the addition of one and of two equivalents of alkali.

Observations of the Afterglow. B. THIEME. (*Deutsch. phys. Gesell. Verh.*, xv, 16, 794.)—A preliminary communication describes briefly several new observations on the afterglow produced in the gas of a low-voltage carbon-filament lamp after a discharge has been passed, by placing it in an alternating field of high frequency (a Tesla field). The conclusion is that the afterglow is a periodic discharge occurring about 30 or 40 times per second, the period becoming smaller the longer the duration of the effect. Experiments on the discharge which occurs when the bulb of the lamp is electrified by friction are also described, with the conclusion again that the discharge is periodic. Further experiments are being made which will be described in a later communication.

Soft Artificial, Frit or French Porcelain. A. GRANGER. (*Bull. Soc. d'Encour.*, cxx, 195.)—A history of the origin and development of the various forms of porcelain, especially those of France and of Sèvres.

Modern soft porcelain dates from 1879, when Lauth found by analysis that the composition of the ware varied considerably with the firing temperature, owing to the volatilization of the alkalies. It was decided to use a more acid frit and Stas glass, which has the composition $\text{SiO}_2 77$, $\text{CaO} 10.3$, $\text{K}_2\text{O} 7.7$, $\text{Na}_2\text{O} 5.05$ per cent., was employed, while the marl was replaced by a mixture of chalk and Dreux clay. The figures for the body mixing were: Sand, 49; Stas glass, 27.5; chalk, 16.66; Dreux clay, 6.86. The chemical composition was: SiO_2 , 80.31; Al_2O_3 , 2.62; CaO , 13.27; R_2O , 3.8; which meant that nearly 5 per cent. more silica was introduced at the expense of the lime and alkalies. More recent mixings, used for ware exhibited at the 1900 Exposition are: Sand, 33; Stas glass, 46; chalk, 14; Dreux clay, 7; with a glaze formula: 0.46 Na_2O , 0.54 PbO , 2.5 SiO_2 . The ware is fired at cone 4 instead of at cone 7, like Lauth's mixing. Still more recently, kaolin has been substituted for Dreux clay, but the composition is not published. This new ware is called soft kaolin porcelain.

Preservation of Hydrogen Peroxide. A. M. CLOVER. (*Amer. J. Pharm.*, lxxxv, 538.)—The addition of 0.05 per cent. of acetanilide to hydrogen peroxide solution increases its stability to such an extent that only about 2.7 per cent. is decomposed in five months. The presence of mineral acids and of salts of the alkalies and alkaline earths has no influence on the stability of the peroxide solution; while traces of copper and iron increase the rate of decomposition.

Canadian Asbestos. ANON. (*J. Roy. Soc. Arts*, lxii, 36.)—The province of Quebec contains the principal asbestos-producing areas of Canada. The present workable deposits are scattered through the great serpentine range which strikes through the townships of Broughton, Thetford, and Coleraine. The total length of the belt is 23 miles, with a width of 100 feet in the extreme easterly part, increasing to 6000 feet in the Mock Lake area. The principal deposits are at Thetford, Black Lake, Danville, and East Broughton; the first two are the most important. The mineral occurs in a series of narrow and irregular veins, sometimes, though rarely, reaching a width of six inches. Large mills are now in operation in which the rock is broken and crushed and the fibrous asbestos is taken up from screens by suction fans, and blown into settling chambers. At present the annual production is over 100,000 tons, valued at upwards of \$3,000,000. It includes a large variety of grades, from the long-fibred crude asbestos, valued at \$300 a ton, down to the shortest mill fibre, valued at only \$2 or \$3 per ton, and "asbestic sand," used for wall plaster, and valued at from 75 cents to \$1.50 per ton.

Radiotelegraphy between Nauen and Long Island. ANON. (*Eng.*, xcvi, No. 2484, 206.)—According to the *Telefunken Zeitung*, an exchange of messages has taken place since the beginning of 1913 between the Telefunken station at Nauen, where the 100-metre tower, which was blown down by the wind, has been brought up to its projected height of 200 metres, and Sayville, on Long Island. This station belongs to the Atlantic Communication Company. The distance is 6500 kilometres, just double that between the west of Ireland and Cape Breton Island, where Marconi stations have been working for some years. By using high-frequency generators Nauen is said to have made successful radiotelephone experiments with Vienna and other places up to 700 kilometres distant. Radiotelegraphic signals over exceptionally long ranges were overheard at Awanui, in New Zealand, which travelled 7800 kilometres from steamers travelling between Honolulu and Yokohama (Marconi apparatus) and at Pennant Hill, in Australia, in which case the signals came from a cargo steamer 6700 kilometres distant (Telefunken apparatus).

Consumption of Aluminum. ANON. (*Metal Ind.*, xii, No. 1, 3.)—More than 65,000,000 pounds of aluminum were consumed in various industries in the United States in the year 1913. This makes a new high record for aluminum consumption.



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ARTIFICIAL DAYLIGHT.*

BY

HERBERT E. IVES, Ph.D.,

Photometrical Laboratory, United Gas Improvement Company.

IN the fourteenth century the Glover's Company, of London, decreed that "no one shall sell his goods by candle light." When Tyrian purple was the staple cargo of the galleys of Phœnicia, it is safe to say that the buyers of that day early learned by experience to make no purchases by torchlight. Certainly it has long been known among those whose business it is to work with colors that daylight and "yellow candle light" are wide apart, not only in appearance, but also in their effect upon colors. It comes, nevertheless, as a surprise to many to learn how numerous are the industries whose working hours depend upon daylight. Color printing and lithography, dyeing, the painting and viewing of pictures, tobacco sorting, the grading of sugar and flour, the sorting of precious stones, the matching of colored fabrics, the inspection of meats and delicate chemical analysis—these are a few having need for daylight at all hours, to say nothing of the surgeon and the dentist.

Among women a knowledge of the defects and pitfalls of artificial light is more general than among men, doubtless because

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the prevailing fashions call for color in feminine attire. In a big store any day, almost any minute, one may see prospective purchasers of dress goods carrying pieces of goods, or having them carried, to the more or less distant windows to learn their true daylight appearance. For a dress must not look well merely by the artificial light over the counter, but out of doors as well, and frequently is good by one and inharmonious or ugly by the other.

The fact that, as a rule, artificial light is greatly different in appearance from daylight need be merely noted at this point. Most artificial lights are more or less yellow as compared with the light of the sun or sky. The difference is usually very great, as any one can convince himself by comparing the two side by side under conditions of approximate equality of brightness for the two. For instance, if two shadows of a pencil are formed side by side by the two kinds of light, such as a tungsten lamp and the sky, the shadow illuminated by artificial light appears orange yellow; that by the sky, deep blue by contrast. Ordinarily we do not appreciate this difference because we do not see the two lights together, and because, if the artificial light is not too strongly colored, the eye by the process of adaptation will in large measure adjust itself to the new distorted color scale—just as a man in walking against the wind unconsciously leans forward. There is a large and interesting problem here for the physiologist and the psychologist to answer: in what way and how much the use of artificial light so different in quality from the light under which the race has been developed may affect the eye and the mind. Certain it is that artificial light is not an unmixed blessing. To its increased use is popularly ascribed many eye troubles. Then, too, many of our habits as social animals seem intimately connected with the use of artificial light. Whether it be the glitter and heat of our ballroom lights, or the odor and dimness of our midnight oil, that work their characteristic stimulation, benefits, depression, or ocular injury, or whether these are to be ascribed to their color, is a problem of interest, but here we shall concern ourselves almost entirely with the severely practical question of producing artificial daylight for industrial purposes.

What is daylight? is the inevitable question, for it is at once evident that the setting sun, a clear blue sky, and a "white"

cloud are markedly different. So, too, the light reflected into our buildings from snow, grass, foliage, from earth, brick pavements, or gray asphalt is far from being a uniform thing. Daylight is, in fact, quite variable in color, a fact which has led professional color matchers to search for the most constant kind of daylight. This they have decided to be the light from a clear north sky. To the eye this is unmistakably blue in color, hence the problem of producing daylight is not necessarily the same as that of producing "white" light.

In order to answer the question: "What is daylight?" it becomes necessary to measure color. We shall, therefore, first pay some heed to the scientific measurement of color. We shall then apply the methods of color measurement to our present illuminants, natural and artificial, and so learn how they differ from each other.

Various ways of producing artificial daylight will present themselves as a result of this study and will be discussed. Next we shall investigate the problem of why and how colors change in appearance in going from one kind of light to another. From this we shall be led to formulate the necessary characteristics of a color-matching artificial daylight. Some account of the practical achievement of artificial daylight, its various forms and its characteristics, will follow. Then a little space will be devoted to a study of the distribution of natural daylight out of doors and in rooms, and the possibility of our ultimately copying, at a not prohibitive expense, both the color and the distribution of natural daylight.

COLOR MEASUREMENT.

There are two distinct methods of color measurement. The first is by analysis of the light radiations into their elements and then quantitative measurement of these elements. The second is by analysis according to the effects on the visual apparatus. Properly speaking, the first method is not color measurement at all, since, as will be seen, a color-blind observer or a thermometer, if sensitive enough, may be used to make the measurements. Nevertheless, our problem is an indeterminate one without such measurements, so that they must be treated in detail.

As every one knows, light may be analyzed or dispersed by means of a prism or grating. Sunlight, when so dispersed, gives

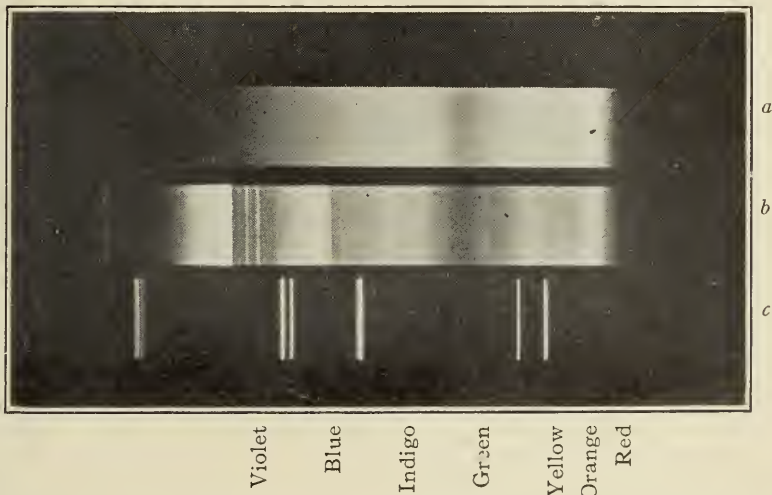
the rainbow or solar spectrum with its numerous colors, of which the principal ones are red, orange, yellow, green, indigo, blue, and violet. Any complete study of color must be a study of colored light, since it is only by seeing colored light that we appreciate objects as being colored. The color of an object is, in fact, determined by the completeness with which it reflects or transmits the light which falls upon it. It owes its color to the existence of that color in the light illuminating it. A red glass is red because it transmits the red of the spectrum. For this reason the whole story of an illuminant's behavior as a revealer of color is laid bare when once the light of the illuminant is analyzed completely. These analyses may be considered in two parts—qualitative and quantitative. Qualitatively we note important differences in the spectra of different light sources. Sunlight, for instance, gives a continuous spectrum with no noticeable breaks from red to violet. A candle gives a similar spectrum, but one which will give us some difficulty in seeing the blue and violet portions, unless we arrange our prism device (spectroscope) in a way favorable to bring considerable light to the eye. A carbon arc light shows a continuous spectrum, but one on which are superposed bright violet lines or bands. A nitrogen vacuum tube exhibits several isolated broad bands of colored light. A carbon dioxide vacuum tube shows numerous fine lines and bands nearly filling the entire spectrum. A mercury arc, representing the extreme from the continuous spectrum, exhibits merely isolated bright lines of light. In short, in the incandescent mercury vapor only comparatively few vibrations are represented, which when communicated to the ether produce light waves of those few wave-lengths only (Fig. 1).

Considerable information bearing on our special problem is furnished by this merely qualitative survey. It is at once evident that a light totally lacking in any color of the spectrum, such as the mercury arc, which is lacking in red, is not capable of showing that particular color in an object. But this qualitative knowledge must be supplemented by quantitative measurements before it has any real use. Such measurements are usually made by the spectrophotometer, which is, in brief, a spectroscope so arranged that each color may be compared in intensity with the same colored light from a chosen standard light. In place of a standard light it is much preferable to reduce the results to an absolute

standard,—*i.e.*, to obtain the intensity of the radiation at each wave-length as indicated by the heating effect. The values which are given here have been so reduced as to show these energy values, as though they had been obtained by the use of a bolometer or thermocouple at the observing slit of the spectrometer.

Fig. 2 plots in the form of curves the relative intensities throughout the spectrum of certain representative illuminants, including sunlight and blue sky, these latter being the mean of a number of observations by different people. The curves as drawn equal $.59\mu$, which is merely a matter of convention, since the

FIG. 1.



Spectra of representative light sources. (a) Continuous spectrum of the Welsbach mantle; (b) continuous spectrum with superposed bands, carbon arc; (c) line spectrum of the mercury arc.

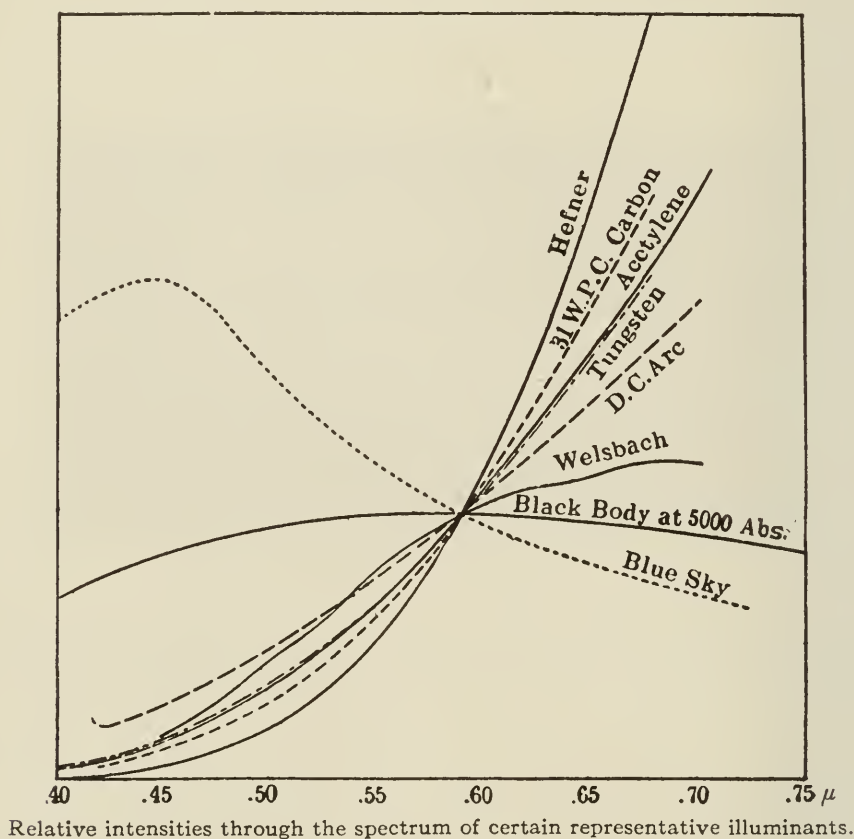
actual relative intensities of the lights are not involved. As a matter of fact, this convention practically means that the lights compared are at nearly the same luminosity.

An examination of these curves yields interesting information. Practically all the common artificial illuminants differ from daylight in having an excess of red, orange, and yellow radiations, with a corresponding deficiency in blue and violet. They lie together in an entirely different family from the varieties of daylight. The latter differ in the blue on this scale by less than the factor two, whereas the ratio between day and the artificial lights is from six to twelve. The physical explanation of this lies in the fact that the common illuminants are incandescent solids at comparatively low temperatures, such as $1500\text{--}2500^{\circ}\text{ K.}$, while

sunlight approximates in color an incandescent solid or black body at 5000° K. The practical effects of this characteristic of the common illuminants, such as the incandescent electric lamp, the Welsbach mantle, the gas flame, etc., are two: First, their general yellow color, and, second, their different effects on colored objects. This latter peculiarity will be treated presently.

The second method of color measurement must now be considered. This is derived through color-mixture experiments. It

FIG. 2.

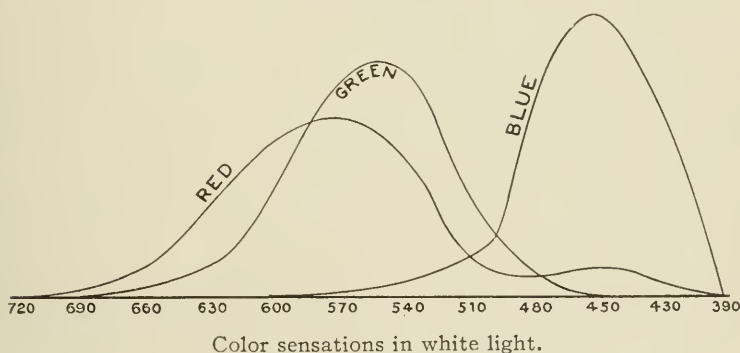


owes its significance to the important fact that colors may look exactly alike which are, nevertheless, composed of quite different radiations, as indicated by the spectroscope. For instance, a mixture of red light and green light produces a yellow which is indistinguishable in hue from a true spectroscopic yellow,—*i.e.*, a color showing nothing but a small region of the spectrum around the yellow. Similarly a mixture of yellow light and blue light produces a white indistinguishable from one in which all the spectrum colors are present. Red and bluish green constitute another

part of these "complementaries," as they are called. The most interesting set of mixture colors, however, are red, green, and blue, for it has been found that from these three may be made not only white, but all the colors of the spectrum, and hence all the colors formed by the addition and subtraction of these; that is, all the colors of nature. It must be clearly understood, however, that these color matches are subjective; that is, they look the same, but of course on analysis with the spectroscope they at once show their composite character.

Now this characteristic of red, green, and blue light has led to these colors being called "primaries." They constitute the smallest number of colors out of which all the others may be produced. As such they have had a notable part in making color photography possible. Here we are more interested in the fact

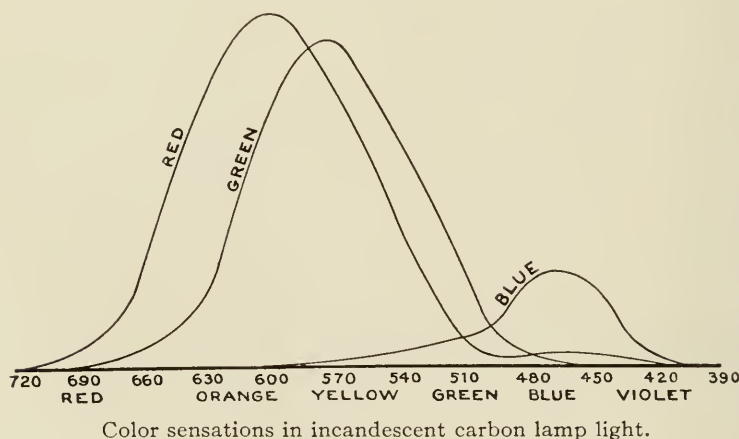
FIG. 3a.



that these phenomena of color mixture furnish a method of measuring and representing colors as they appear to the eye, irrespective of their composition.

Taking the spectrum of white light as our standard, it is possible by a series of experiments to determine the quantities of red, green, and blue necessary to match each of the other spectrum colors. Curves may thus be plotted representing these facts, and are called color-mixture curves of the spectrum. This has been done, and it has been found that the true primaries are a certain red, green, and blue a little purer and more saturated than any ordinarily found in the spectrum. These experimentally indicated true primaries are called the primary or fundamental sensations. Fig. 3a shows their distribution in the spectrum, where the units are chosen such that equal quantities of the three sensations give white.

A color may now be specified in terms of but three quantities, instead of a dozen or more, as is necessary with the spectrophotometer. White is equal quantities red, green, and blue sensation; yellow is so much red sensation and so much green, as may be read off the curves. A complex color such as that of an illuminant may be evaluated by multiplying its spectrophotometric value at each wave-length (as compared with white light) by the values of the three sensations at the corresponding wave-lengths and then integrating the curves. Thus the values derived by the use of the spectrophotometer may be translated into sensation values. This transformation process is indicated by the curves of Fig. 3*b*, in the case of a carbon incandescent lamp.

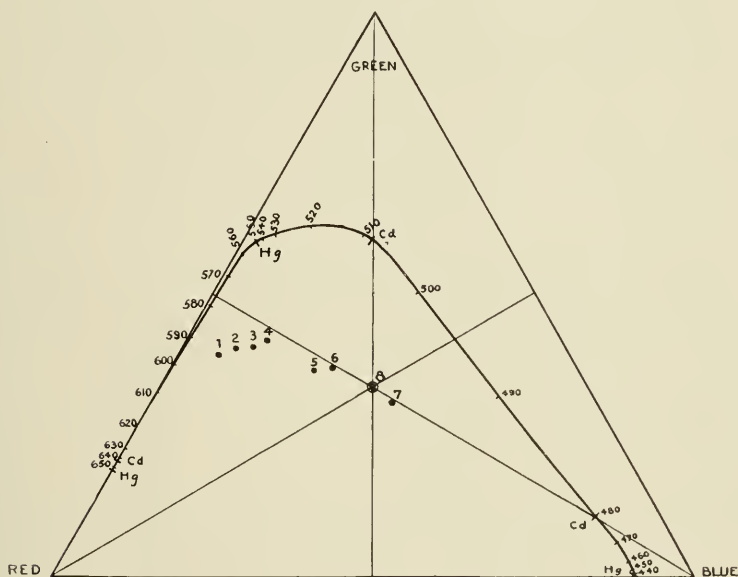
FIG. 3*b*.

Still another way to obtain the sensation values is by actually making mixtures of red, green, and blue light to match the color under measurement. If one knows the sensation values of the red, green, and blue lights mixed, the results may be at once translated into terms of the fundamental sensations. Some results of transformations to color sensations from both kinds of measurements of color are shown in the color triangle, Fig. 4.

The results of measurements in terms of color sensations lend themselves to an elegant and useful diagrammatic representation in what is called the Maxwell color triangle, which we shall have occasion to use later. This triangle is shown in Fig. 4, where the three fundamental sensations are indicated at the three vertices, white at the centre and the various spectrum colors in their

appropriate positions around the triangle. A certain property of an equilateral triangle is here utilized; namely, that the sum of the vertical distances of any point from the three sides is equal to the altitude. If, then, the three sensations which constitute a color be represented in such units that their sum is the altitude of the triangle, every color finds a place in it. White, being equal parts of the three sensations, lies at the centre.

FIG. 4.



Color triangle, showing positions of spectrum colors and representative illuminants.

- | | | |
|--------------|-------------------|--------------------------|
| 1. Hefner. | 4. Welsbach. | 7. CO ₂ tube. |
| 2. Carbon. | 5. D. C. arc. | 8. Whole light. |
| 3. Tungsten. | 6. Afternoon sun. | |

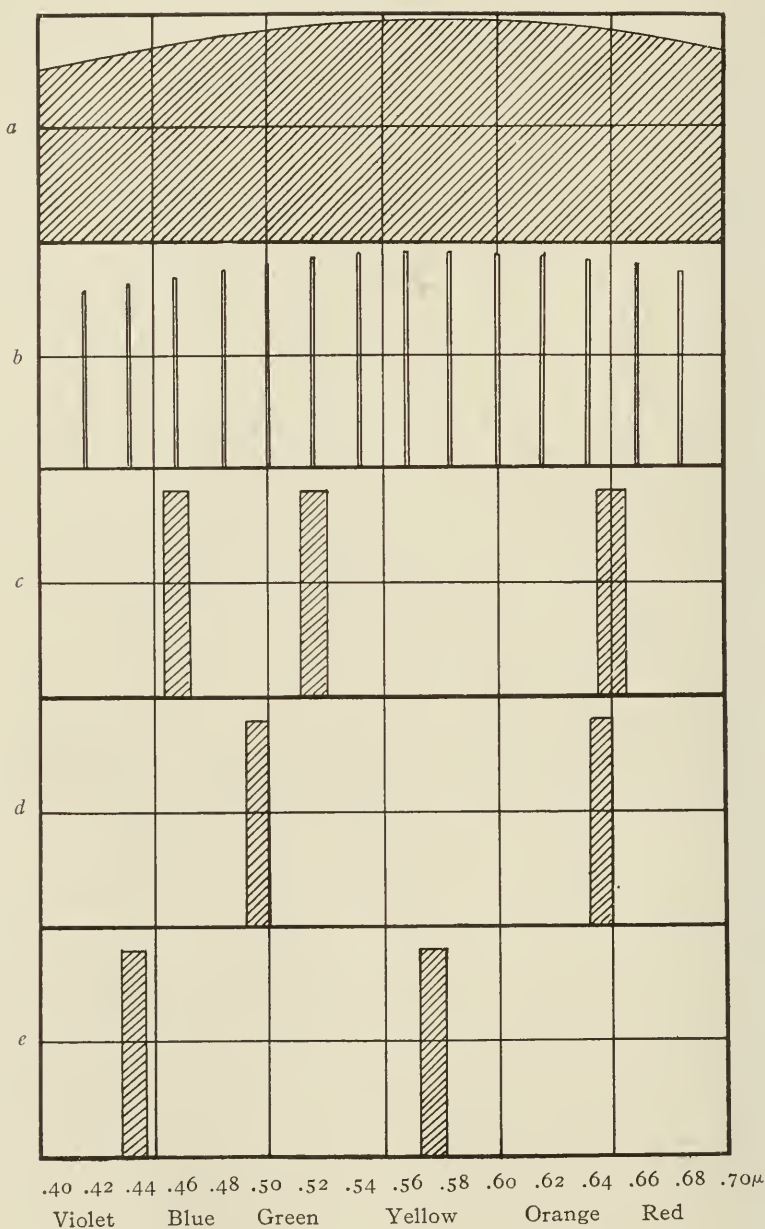
An interesting and valuable property of the triangle is that mixtures of two colors lie on the line joining them. Thus the yellow lies on the line joining red and green. White lies on the line joining a large number of pairs of colors, the "complementaries" met with above. We can then read off from this triangle what colors are to be mixed to produce any others, among them white.

The various sensation values for different illuminants are plotted in the triangle of Fig. 4. This plot again shows how most artificial illuminants differ from white toward yellow, as they are much nearer the yellow of the spectrum than the white centre.

METHODS OF MAKING WHITE LIGHT.

As a result of the study of color measurement several methods of artificially making white light present themselves. First and

FIG. 5.



Various ways of making white light. (a) Continuous spectrum; (b) a large number of lines or bands; (c) a mixture of red, green and blue, (d) a mixture of red and blue-green, (e) a mixture of yellow and blue.

most obvious, theoretically, is the production of an illuminant that has the same distribution of intensity throughout the spectrum

as a chosen daylight standard. For instance, if the standard be taken as the color of an incandescent solid at 5000° C. absolute, the direct way to make artificial daylight would be to heat a solid to such a temperature. This, of course, we know is impossible with our present facilities for high temperatures and our known refractory substances. Some form of selective radiation, as from certain oxides as yet unstudied, or from gases under electrical discharge, must then be looked to as a possible means of securing directly, without prohibitive temperature, the desired energy distribution in the spectrum.

A second method is to subtract, as by a process of absorption, those radiations in an illuminant which are present in excess over daylight. The manner of accomplishing this theoretically is indicated by Fig. 11, where an ordinary artificial illuminant (excess in red, orange, and yellow) is to be made to match daylight. Starting with a point on the extreme blue of the spectrum, progressively greater portions of the illuminant's radiations are to be absorbed, as indicated by the area of the curve above the cross-hatched portion. Assuming the absorption performed, there remains a spectrum identical in every respect to the standard white light.

A third method of producing white light is indicated by the color-mixture experiments; namely, by the mixing of two or three colors respectively complimentary. Fig. 5 shows an illustration of how white light might be made up of (*a*) a continuous spectrum, (*b*) a large number of lines or bands, (*c*) a mixture of red and blue green, (*d*) a mixture of yellow and blue, and (*e*) a mixture of red, green, and blue, the proper quantities of each being taken so that the total of each fundamental sensation is in every case the same.

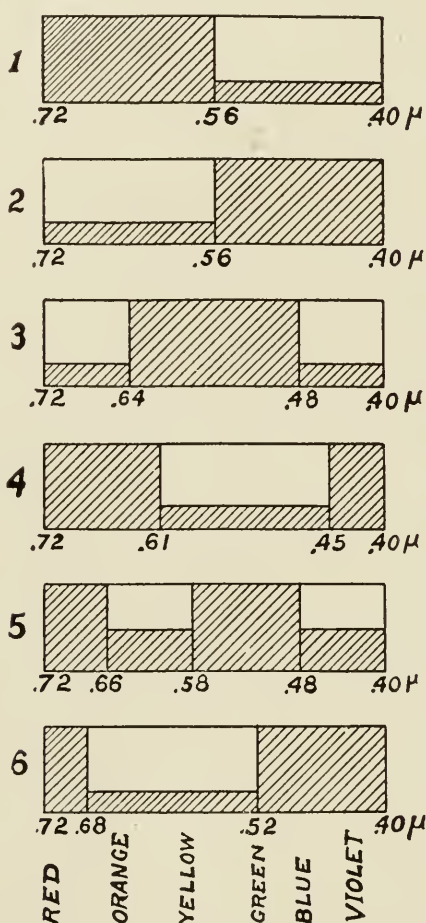
With these various means at our disposal it becomes necessary to establish criteria upon which their relative merits may be decided. Among such criteria are efficiency and suitability for color matching. The latter requirement is the most important one here, and will next be considered.

THE REQUIREMENTS OF A COLOR-MATCHING ILLUMINANT.

What is the relationship between the color of an illuminant and the color of the illuminated object? An answer in one

simple case is straightway evident. If the illuminant lacks the spectrum rays which by reflection from a surface constitute the color of the surface, then the illuminant obviously is useless for revealing whether two such non-reflecting surfaces are the same color or not under other and more usual illuminants. But if all the spectrum colors are present, though with varying intensity,

FIG. 6.

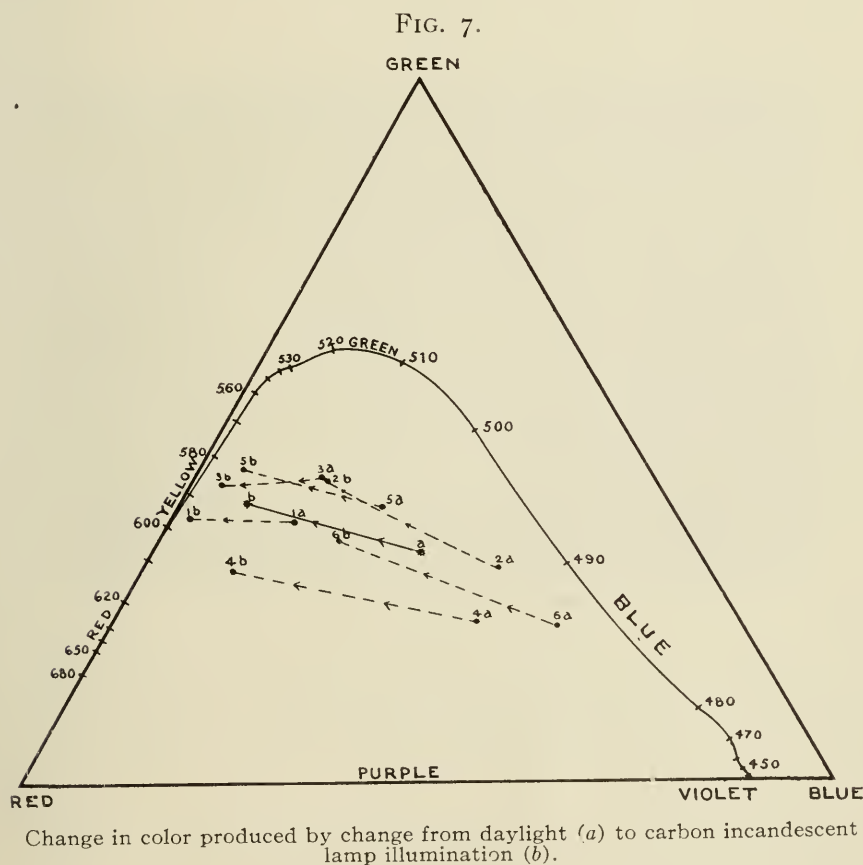


Spectral composition of certain arbitrary colors; reflecting power of surfaces or transmissions of absorbing media.

it is not so easy to answer the question at issue. We must have recourse to the methods of measurement above outlined.

Let us take a representative color, such as is to be found in a dyed fabric. With a spectrophotometer determine its reflecting power at each wave-length of the spectrum. If we multiply the values obtained by the values of the sensation curves in two

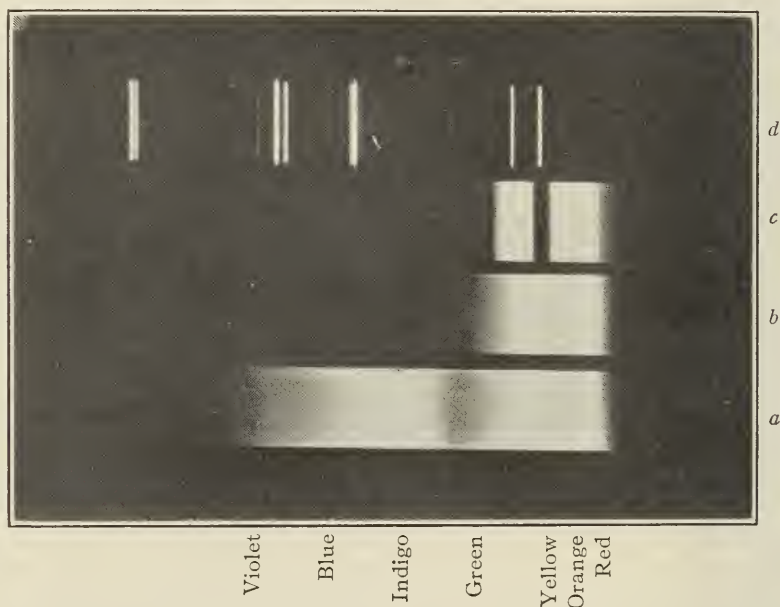
illuminants under study, we arrive at the resultant sensations as excited by the light reflected from the fabric under the two different lights. These values may then be tabulated or plotted in a color triangle showing the change in the color of the surface under the different illuminants. On carrying through this operation for the set of arbitrary colors shown in Fig. 6, under daylight and under carbon lamp light, the color triangle data of Fig. 7 were obtained. It is to be seen that, while pure spectrum



colors change not at all (since they have no various spectral components to be altered in relative intensity), the colors nearer white are bodily shifted in hue. Purples become reds, greens turn to yellows, and so on. This illustrates the change of color appearance, which is very marked, for the kind of illuminants compared, with purples and lavenders (which become ruddy), blues (which become black), yellows (which appear less strongly colored). But the question of color matching is the paramount one. If two colors match under one illuminant, will they match

under another? The answer is evident if we consider the two possible kinds of matches. If we have two yellows, identical as to reflecting power through the spectrum, obviously they will continue to match under any illuminant, since both will be affected alike. But suppose one of them is a mixture of red and green, the other a spectrum yellow. Under white light they are identical in appearance. But when they are placed under a light different in composition, such as a carbon incandescent lamp, the red ele-

FIG. 8.



Cause of change of appearance of colors of different composition when viewed under different illuminants. (a) Continuous spectrum light source; (b) and (c) two yellow solutions which appear exactly alike when illuminated by light source (a); (d) line spectrum. Solution (c) absorbs one of the principal lines of this spectrum and consequently appears different in color from (b).

ment of the composite color is unduly accentuated, the green element insufficiently brought out, and the resultant appearance is not the same as that of the simple yellow. This difference may be shown numerically by the use of the color sensation curves and the color triangles. It is illustrated for an extreme case by the spectrograms of Fig. 8. Here are shown (a) a continuous spectrum light (Welsbach mantle), (b) and (c) the spectra of two yellow solutions which match perfectly under this light, and (d) a discontinuous spectrum (mercury arc). Note that the absorption band in the second yellow falls exactly over the yellow mercury line; the mercury arc light viewed through this solution

is bright green; through the other solution it is yellow. The two solutions look exactly alike by one light, totally different by the other.

It is obvious, from these considerations, that if an artificial daylight is to behave toward all kinds of colors exactly as does real daylight, it must not only look like daylight, but must be identical with it, wave-length by wave-length through the spectrum.

THE PRACTICAL ACHIEVEMENT OF ARTIFICIAL DAYLIGHT.

Before proceeding to an account of various artificial daylights let us here review briefly the pertinent facts about daylight and color. We have seen that daylight is variable, but that it always lies in a class apart from the usual artificial light sources, which latter are in general of a yellow color. We have seen how color may be exactly measured, and have learned that the same color appearance may be produced in several ways. Several theoretical ways of producing artificial daylight have been described. Finally, by investigating the changes in the apparent color of objects under different colors of light, we have been led to formulate the essential characteristic of artificial daylight; namely, it must not only look like daylight, but also be like it, as shown by an analysis of the spectrum.

In approaching the practical side of the problem it becomes necessary to choose a standard for daylight, and it becomes necessary to know what degree of approximation to the last-named criterion is sufficient for practical purposes. It is also necessary to pay attention to the matter of efficiency—the artificial daylight must not be prohibitive in cost.

The standard of white light adopted by the writer is derived from the mean of a large number of spectrophotometric determinations of sunlight quoted above, into which an additional factor has been introduced. It is always desirable to connect any standard with other standards; to depend not on a set of numerical values, but on some simple mathematical expression which may be developed by the introduction of a few constants. It appears, for instance, that the white light standard mentioned has to within the limits of accuracy of its determination the distribution of intensity through the spectrum of a perfect incan-

descent solid or black body at 5000° C. absolute; a distribution immediately calculable from the laws of black body radiation. So much for a scientific standpoint. In commercial practice another fact has had to be given weight; namely, professional color matchers have chosen as their standard light the blue north sky. It is difficult to change the customs of experts, and so it became practically necessary to supply a blue sky standard. For this the spectrophotometer values given in Fig. 2 serve as a basis.

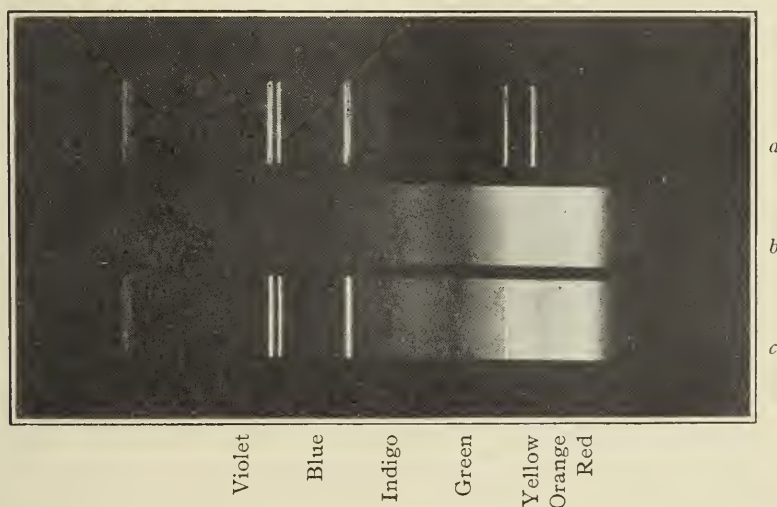
How closely is it necessary in practice to approximate the exact spectrum distribution of daylight? Very closely indeed, but not so exactly as to be prohibitively difficult, for this reason: that all ordinary colored objects and coloring materials have rather long diffuse spectra; they are not isolated, sharply defined spectrum colors. Consequently, if such gaps and irregularities of the artificial daylight spectrum are bridged over by the reflection spectrum of the color illuminated, they will not be noted. For instance, an illuminant whose spectrum consisted of twenty-five or thirty equally spaced lines would probably behave excellently as a color-matching light, provided, of course, their intensity was closely that of the daylight spectrum at each point. An expert with a knowledge of the spectrum and of the kind of coloring media used in the arts can make up critical colors having several maxima of reflecting power in the spectrum, colors which match under one light but not under another, and from the accumulated experience of the practical dyer other colors may be found of similar difficult character. The behavior of these colors under an artificial daylight in its experimental stages provides valuable information and guidance.

The question of efficiency will be considered in connection with each of the three kinds of artificial daylight described below.

The first kind of artificial daylight postulated as possible is a light source that has naturally the same spectrum distribution of intensity as daylight. An incandescent black body at 5000° C. absolute would have this distribution, but such a temperature is entirely beyond our present means. The same distribution could be obtained at much lower temperatures if we had available a selectively radiating substance which would give out a comparatively small amount of invisible heat radiation and have a much greater emissivity at the blue end of the spectrum than at the red. Such a substance is not yet known, but the materials used in the

Welsbach mantle approximate the characteristics to a degree which incites us to further study of these oxides. Another possible way of achieving this spectrum distribution is through non-temperature radiations, as, for instance, by the passage of a current of electricity through a rarefied gas which would radiate at a sufficient number of wave-lengths in the right proportion. Such an artificial daylight has been found in the radiation from the carbon dioxide vacuum tube, which under the name of the Moore tube has been developed commercially and has deservedly been used to considerable extent for color-matching

FIG. 9.

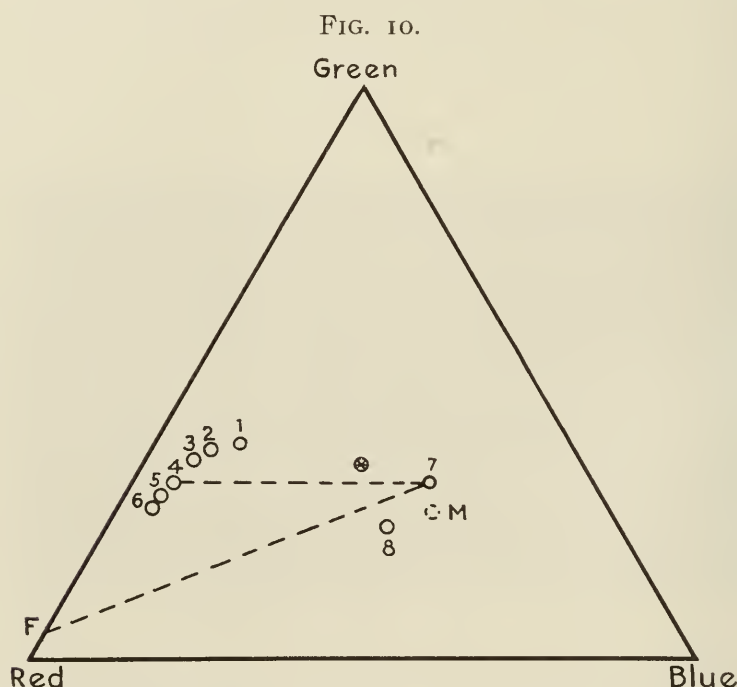


Additive production of artificial daylight. (a) Mercury arc spectrum; (b) tungsten lamp spectrum; (c) combination of mercury arc and tungsten lamp light to make a white light.

work. Its spectrum consists of many fine lines and bands, together giving the color of a light blue sky and of reasonable uniform intensity. The Moore tube is, however, comparatively inefficient and demands an expensive installation of alternating current and transformer to produce high potential—drawbacks which have prevented its extensive use.

The second kind of artificial daylight I wish to treat of here is one of interest from the standpoint of color measurement and theory. So far as concerns the question of color matching, this particular daylight,—namely, the one made by matching pairs of colors to look like daylight,—is chiefly of importance as illustrating the pitfalls to be avoided.

A property of the color triangle above referred to is that colors lying on opposite sides of a line passing through the centre of the triangle (white) mix to produce all colors lying on that line, among them white. Consequently, if two happen to lie thus on opposite ends of a line through the centre of the color triangle, it should be possible to make a white-appearing mixture. Examination of the color triangle, Fig. 10, shows that the mercury vapor arc lies opposite the tungsten lamp. Consequently, if



Illustrating white-appearing lights made by combining the mercury arc with other illuminants; 1, 2 and 3, Welsbach mantles; 4, tungsten lamp; 5 and 6, tantalum and carbon lamps; 7, mercury arc; *F*, color of fluorescent reflector; 8, mixture of mercury light from lamp and reflector (*M*) with *F*.

these two illuminants act together the appearance should be that of white light. Such is, in fact, the case. White-appearing light can be so produced at an efficiency somewhere between that of the two constituents, and white light of this constitution is to be found in several places. The term "additive" production of artificial daylight may be applied to this process to distinguish it from the other process presently to be described as "subtractive." This particular "additive" daylight, and others which are apt to be produced experimentally in efforts to make a true artificial daylight, are characterized by their failure to show up colors in their true daylight appearance. The reason for the

failure of this particular combination is easily seen from the spectrograms of Fig. 9, where the tungsten lamp spectrum is shown, with its deficiency in blue; the mercury arc spectrum, deficient in red, and the combination of the two. The latter is characterized by long gaps and irregularities. The mercury arc-tungsten combination is not, therefore, suited for one use to which it has been mistakenly put; namely, the illumination of picture galleries.

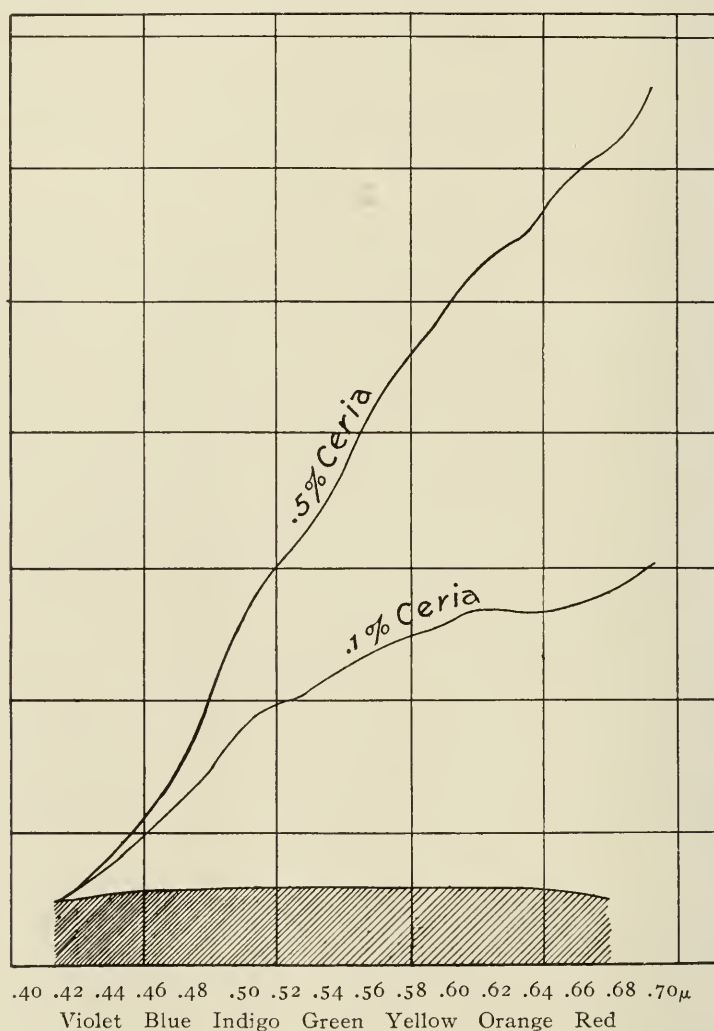
Another example of this additive method of producing white light is furnished by the Cooper-Hewitt lamp with fluorescent reflector. The fluorescent substance—rhodamine—is of a color approximately complementary to the hue of the mercury arc, as is shown in the color triangle of Fig. 10, where the fluorescent light is shown at *F*, the mercury arc at 7, and the "white" light at 8. This is not exactly on the line joining 7 and *F*, because the mercury arc light reflected from the rhodamine reflector is deficient in green. The real mixture is between *F* and *M*. It will be seen that the resultant color is a purplish-white (below centre of the triangle). This light is, unfortunately, not suited for delicate color matching, because its spectrum is merely the mercury lines with an orange-red band added. Large portions of the spectrum are missing.

The next, and on the whole the most important, method of producing artificial daylight is the subtractive one; that is, the subtraction by absorption of those radiations which an illuminant emits in excess over daylight.

By way of detailed explanation let us now carry through the various steps in the practical production of such an artificial daylight. Let us take as our illuminant to be transformed to daylight the Welsbach mantle, which, because of its nearer approach to whiteness than the usual incandescent solids, especially recommends itself for the purpose. The first step is to determine its distribution of intensity throughout the spectrum and compare it to that of daylight. At once cognizance must be taken of the fact that the color (intensity distribution) of a mantle depends upon the composition. A pure thorium mantle is much whiter than a mantle of pure ceria, the light of the latter being, in fact, deep orange-yellow. Fig. 11 shows the energy distribution of two typical mantles, containing .25 per cent. and

.50 per cent. ceria respectively, each compared with daylight under such conditions that the intensity at the extreme blue end of the spectrum is equal. When these data are so plotted the space between the mantle curves and the daylight curve represents light which must be absorbed. It is obvious that the whiter

FIG. 11.

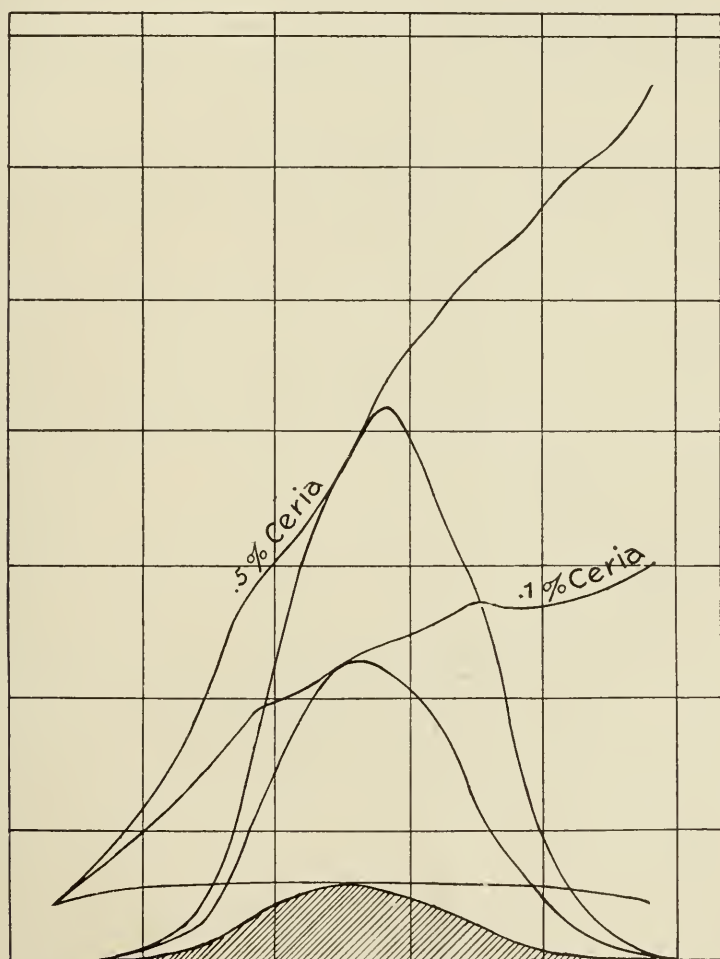


Typical Welsbach mantles compared spectrophotometrically with daylight.

the mantle (*i.e.*, the smaller the percentage of ceria) the less light must be absorbed in order to leave daylight. As yet, however, the amount of this absorption is not expressible in useful comparative units. It is necessary to express this in terms of luminosity. This is done by replotting the data of Fig. 11, multiplying the value at each wave-length by the relative brightness of

that kind of radiation as is done in Fig. 12. Now the area of the "white" luminosity curve, compared to the area of the mantle curve, gives us at once the relative amount of light left after the subtraction process. This ratio I have called the "daylight efficiency." Its value for mantles of various percentages of ceria

FIG. 12.



.40 .42 .44 .46 .48 .50 .52 .54 .56 .58 .60 .62 .64 .66 .68 .70 μ

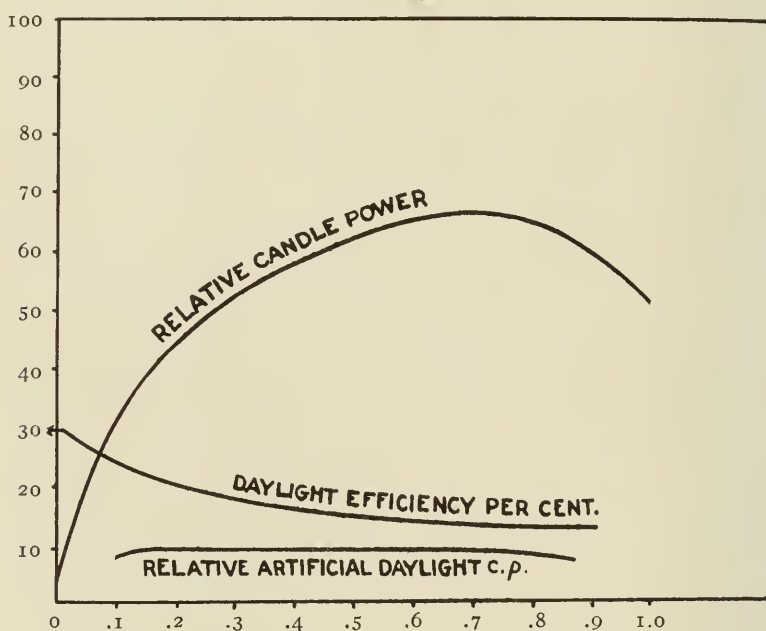
Violet Blue Indigo Green Yellow Orange Red

Calculation of daylight efficiencies of different mantles.

is plotted in curve *a*, Fig. 13. Other things being equal, it is clear that the mantle with no ceria should be chosen. But other things are not equal, for with varying percentages of ceria the candle-power of a mantle changes, rising from a minimum for the pure ceria one to a maximum for a mixture of 99 per cent.

ceria and 1 per cent. of thoria, then again decreasing as the ceria content is increased. This curve of relative candle-power is also shown in Fig. 13. It is obvious that the product of curves *a* and *b* will give the total daylight efficiency of all mantles when screened to make artificial daylight. This product is shown in curve *c*, interesting as showing that mantles through quite a range of composition—from .25 per cent. to .7 per cent. ceria—can yield the same efficiency of artificial daylight. Above .7 per cent. ceria the efficiency drops off rapidly. This efficiency is only

FIG. 13.



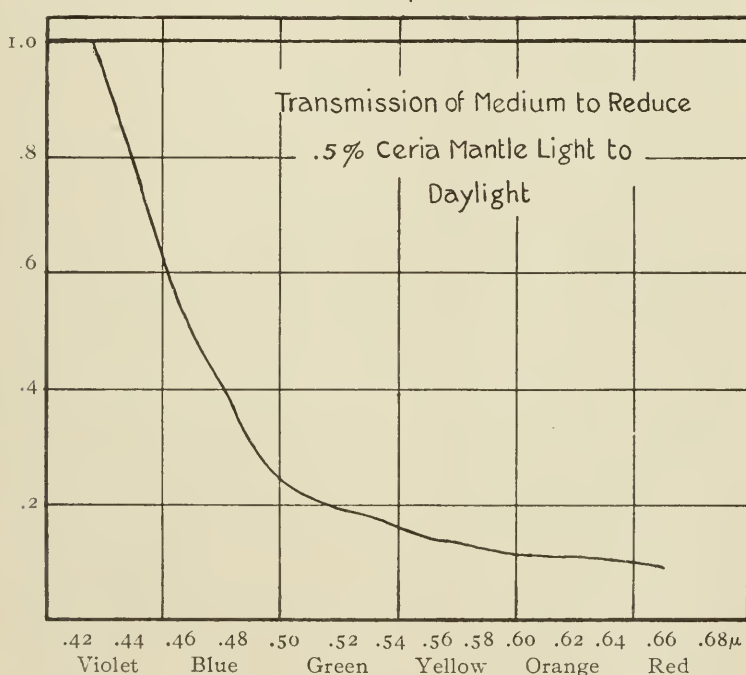
Total efficiency calculations for mantles of various compositions.

about 15 per cent., showing that artificial daylight is necessarily an expensive product when thus secured.

Having chosen a mantle to be screened, the next question is that of absorbing media. What is the absorption needed? Putting it in terms of transmission it is this: The transmission at each wave-length must be the ratio of the daylight intensity to the artificial light intensity when so represented that the value is unity for the extreme end of the spectrum. The transmission required to transform the light of the Welsbach mantle of .5 per cent. ceria to "white" (black body at 5000° C. absolute) is

shown in Fig. 14. It appears that the absorbing medium indicated is of general blue color. The next step is to study the various available absorbing media. These are practically reduced to two: first, colored glass, and, second, dyes which may be incorporated in gelatine or some similar transparent carrier. No single glass or combination of glasses at present on the market possesses the absorption called for. Cobalt blue glass, which is the first thought of every one, has several irregular bands, not a uniformly increasing transmission toward the blue end of the spectrum. Copper

FIG. 14.

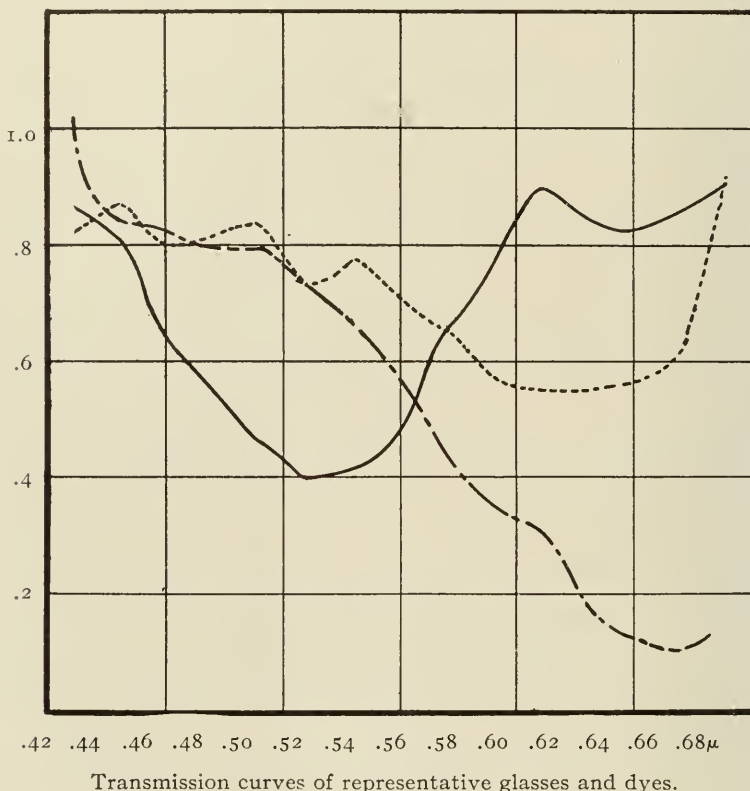


Transmission of medium to reduce light from .5 per cent. ceria mantle to daylight.

glass, which is blue-green in color, has a gradual absorption, but is too green. The great advantages of glass over dyed gelatine are its permanence and the possibility of working it into all shapes, from flat sheet to spherical enclosure. Still, dyes have the one advantage that they provide an enormous number of absorptions of both broad and narrow types. Some representative transmissions are shown in Fig. 15. The bands and deficiencies of glasses can almost always be filled in by properly chosen dyes, although many dyes are not at all permanent, which reduces very materially the number available.

It has been found possible to make a practical combination of copper glass in sheet form with a dyed gelatine layer on a separate sheet, which accomplishes the purpose admirably, using dyes of great permanence. The commercial device is shown in Fig. 16. It consists of a small booth, closed at back and sides, in order that stray light from other light sources may not enter and mix with the daylight. Samples of cloth, tobacco, etc., are held under

FIG. 15.

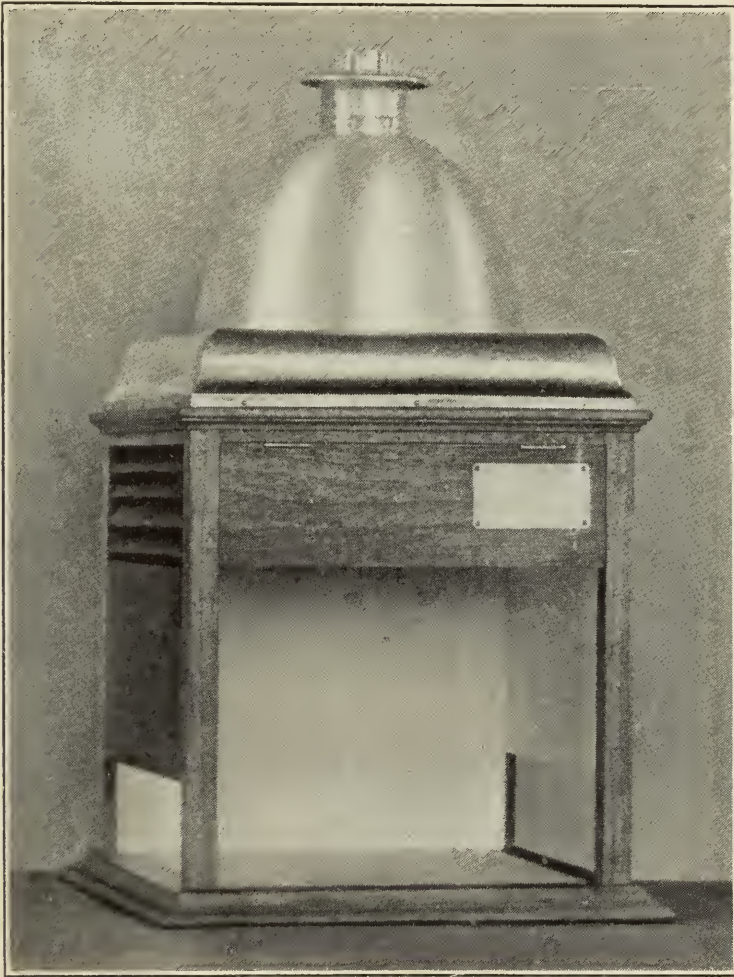


the glasses, and the result is identical with daylight. The spectrophotometer intensity curve is shown in Fig. 17, both for a .7 per cent. ceria mantle, which gives the sunlight color, and for a .25 per cent. ceria mantle, which gives the north light used by dyers and color matchers.

With the .25 per cent. upright mantle more than 20 ft. candles illumination is obtained on the working plane, while with a large inverted mantle the figure is multiplied by four—in either case sufficient for color-matching purposes. The absorption of light by the glasses is about 90 per cent. The device has been

worked out in the booth form partly because the expense of lighting large areas would be excessive, were there not some good reason for so doing, which often there is not, and partly to educate the user to exclude stray light of other colors which

FIG. 16.



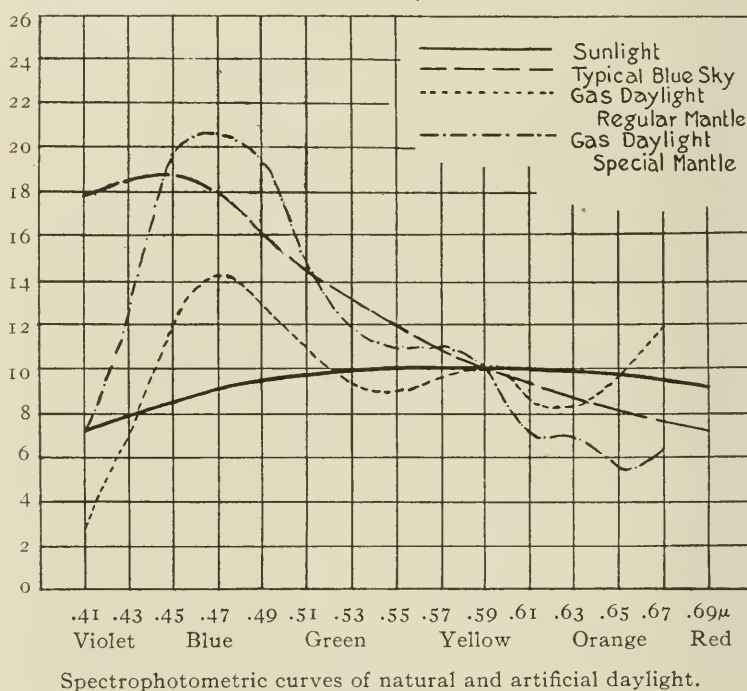
Color-matching booth.

would distort his color values. These devices are now being used extensively in silk mills, cigar factories, department stores, etc.

A limitation to this form is its lack of flexibility, caused by the necessity for using dyed gelatine, which can be laid down only on a flat plate. The extreme desirability of effecting the entire absorption through glass has long been apparent, and in

the Research Laboratories of The United Gas Improvement Company a small experimental glass plant has been actively engaged in the problem of producing such glass. All known coloring oxides have been studied, and Mr. Edw. J. Brady, in charge of this particular research, has recently succeeded in producing a true daylight glass. This glass will shortly be available for gas and other illuminants, and will make artificial daylight as easy to produce as any other artificial light—necessarily at a larger cost, to be sure; but in many cases this larger cost will be an insignificant item compared with the twelve or more additional working hours furnished by artificial daylight.

FIG. 17.



Spectrophotometric curves of natural and artificial daylight.

Before leaving this subject of the production of light having a daylight color, one of the methods of using the absorbing medium claims attention. Colored objects, it must be remembered, owe their color to the effect on the light incident upon and reflected from them. Now, it is immaterial whether the light is subjected to the day-color producing absorption before or after its incidence on the colored object. Except for considerations of convenience, the absorbing glasses could just as

well be placed vertically in front of the booth in Fig. 16, and the colored samples placed in the direct light of the illuminant. Advantage is taken of this alternative possibility in the construction of the daylight spectacles, shown in Fig. 18. Built with a perfectly light-excluding hood, these may be worn by the surgeon

FIG. 18.



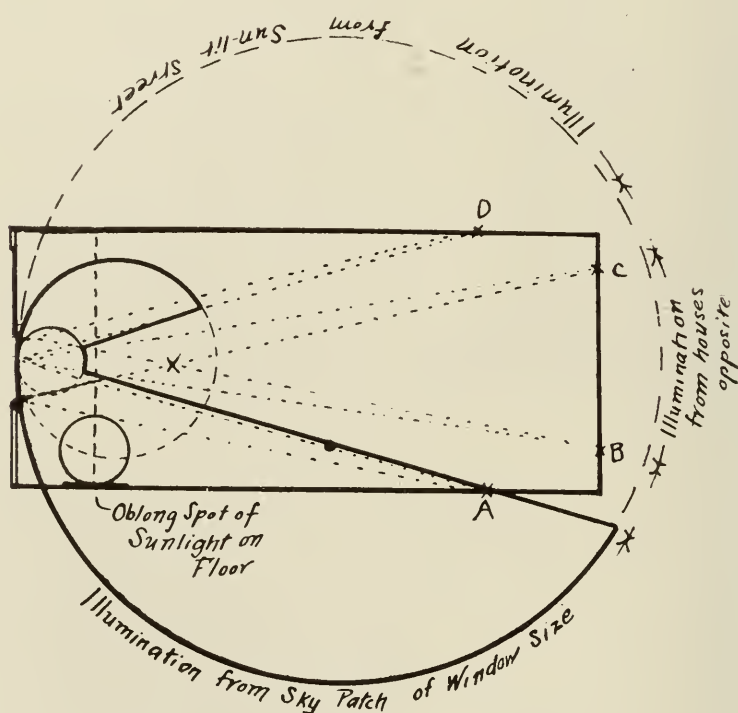
Manner of using daylight spectacles.

or the color matcher, and when used with the appropriate light source they produce daylight for him alone, thus obviating the necessity for a special booth or room in which to do his work. Further advantages of this form of color-matching device are the small amount of special glass needed and the entire freedom from questions of breakage through overheating.

THE COST OF A COMPLETE COPY OF DAYLIGHT.

The question always asked about artificial daylight is: How much does it cost to make a complete copy of daylight illumination in a room? Some figures which I have given elsewhere in connection with a study of the distribution of daylight may, therefore, be of interest here. Pleasant daylighting of the room taken for study, a room 16 feet x 10 feet, was produced when the light of the sky illuminated the whole floor of the room and

FIG. 19.



The distribution of daylight from a window.

when the ceiling was illuminated by the light reflected from the street below, while the opposite houses, which were in shadow, were the only outside objects visible to the occupants of the room. The bright sky, which does most of the lighting of the room, forms a concealed light source. The distribution of light from the window as a light source is shown in elevation in Fig. 19. It was found possible by a construction of mirrors to closely duplicate this distribution and to produce an illumination about one-tenth that of real daylight at an expenditure of about 260 watts. To secure daylight intensity would have taken 2000 watts.

whereas if the light had all been subjected to daylight-producing absorption it should have required 20,000 watts.

If, however, daylight could be produced directly in an illuminant without any waste heat radiation, it would not only be a much more efficient process than that indicated, but even more efficient than any present known artificial light source. Instead of 20,000 watts, 50 watts would suffice.

The ultimate goal of the student of artificial daylight, therefore, is the production of daylight whenever and wherever it is wanted, distributed in any desired manner, at no greater cost than our present yellow artificial light.

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Value of Explosives for Engineering. ANON. (*Amer. Mach.*, xxxix, No. 24, 996.)—The greatest engineering works of the present day are undoubtedly those connected with the removal of vast quantities of soil and rock. The Panama Canal, the Catskill Aqueduct and many other tunnels, excavations and mines are the feats which arouse popular enthusiasm. These would be quite impossible if it were not for the knowledge we have of powerful explosives and modern drilling methods. It is interesting to note that gunpowder as an explosive agent was not used in mines in Europe till a century and a half after the discovery of America, and was first used in Germany. It is only within the last fifty years that mine excavations have been revolutionized by the development of these fundamental requisities, dynamite, the air-compressor, and the power drill.

New Process for Welding Copper. W. SCHIEBER. (*Chem. Zeit.*, xxxviii, 188.)—The two pieces of copper, placed in position, are heated at the proper point by the oxyhydrogen blowpipe until the requisite degree of softening is attained. Complete reduction is then effected in a flame of specially purified hydrogen, and the welding is completed by hammering. It is claimed that the joint is invisible and that the area of juncture is homogeneous in every way with the rest of the metal.

Improving the Properties of Aluminum. A. NEUBURGER. (*Elektrochem. Zeits.*, xx, 295.)—Alloying with 9 to 12 per cent. of cobalt improves aluminum, but it is still deficient in mechanical strength on account of its coarse crystalline structure. This defect can be overcome by the addition of a small proportion of tungsten or molybdenum, yielding alloys with a tensile strength three times that of pure aluminum. The best results are obtained with: tungsten 0.8 to 1.2 and cobalt 8 to 10 per cent., or molybdenum 0.6 to 1.0 and cobalt 9 to 10 per cent. The forging and rolling qualities diminish and the tensile strength increases with increasing content of tungsten or molybdenum and cobalt. The alloys containing tungsten are somewhat harder than those containing molybdenum.

Excessive Leaf Growth of the Beet. A. VIVIEN. (*Bull. Assoc. Chim. Sucr.*, xxxi, 501.)—Comparative investigations of beets grown on soils treated with (1) abundance of organic nitrogenous manure, (2) little or no manure, showed that in the former case the leaf growth was excessive and the roots contained a lower percentage of sugar. These results do not support the view that the sugar is elaborated only in the leaves.

Metallurgy of Steel-refining in an Acid Electric Furnace. A. MÜLLER. (*Stahl und Eisen.*, xxxiv, 89.)—The most important reaction is the passage of silicon into the steel from the lining and the silica-rich slag. This silicon has a considerable deoxidizing action, and makes it unnecessary to add any deoxidizers. No final desulphurization nor dephosphorization takes place. A certain amount of desulphurization is effected probably by the formation of volatile silicon sulphide at the arc temperature, but this only balances the sulphur contained in the coke, etc. The most suitable slags contain about 15 per cent. CaO, 2 to 5 MgO, 10 to 15 MnO, about 4 FeO, and 55 to 60 per cent. SiO₂. Whilst the working of an acid electric furnace requires care and experience, it is considered that where suitable material is available it has the advantages over the basic furnace, for the production of medium quality steel, of smaller current consumption through a shorter refining period, a saving of deoxidizing additions, cheaper first cost and upkeep of the lining, and cheaper fluxes.

MILD STEEL AND ITS TREATMENT.*

BY

ALBERT SAUVEUR,

Professor of Metallurgy and Metallography, Harvard University,
Member of the Institute.

FOR the purpose of illustrating metallographic methods and their teaching we may select as a concrete example the treatment of mild steel, a metal so widely used in machine construction, as, for instance, in the manufacture of shafts, and extensively used, also, for a great variety of steel castings. Such steel may contain some 0.30 per cent. carbon and should be of good commercial quality; *i.e.*, should not contain over 0.1 per cent. phosphorus—preferably not more than 0.05 per cent. of that element—nor over 0.05 per cent. sulphur. According to the treatment it has received it may have a tensile strength varying between 60,000 and 100,000 pounds per square inch, while its ductility measured by its elongation may fluctuate between 15 per cent. and 35 per cent. As cast into ingots or other forms this metal shares the shortcomings common to all steel castings,—weakness, lack of ductility, and little resistance to shock. These unwelcome properties of steel in its cast condition are due primarily to the structure of cast steel, which is very coarsely crystalline.

It is well known that the properties of steel may be very greatly improved through properly conducted mechanical and thermal treatment, by which its structure is modified or refined, and it is the purpose of this paper to describe briefly the various structures mild steel may be made to acquire as the result of work and of heat treatment, and to point out the relations existing between each structure and corresponding physical properties, such as hardness, strength, and ductility.

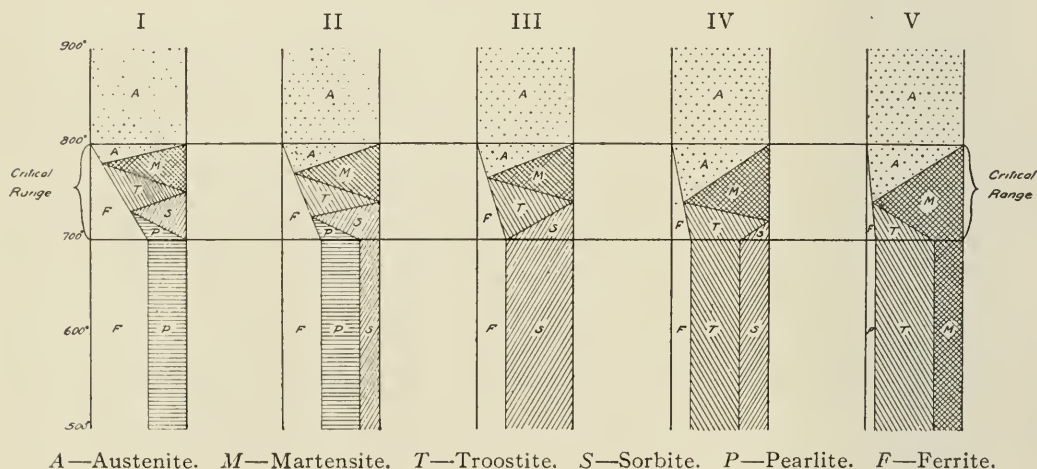
No explanation of the deep structural changes resulting from certain treatments can be given without reference to the thermal critical range of the steel considered. Fortunately, metallography

* Lecture delivered February 6, 1914, before the Mechanical Engineering Society of the Worcester Polytechnic Institute, Worcester, Mass., and communicated by the author.

has so diffused this fundamental knowledge that at the present time there is hardly a metallurgist or metallurgical student ignorant of it. A lengthy description of the occurrence of the critical range of mild steel and of its meaning will not be, therefore, necessary. It will be helpful, however, for the present purpose to illustrate graphically the relations existing between the critical range and the structural changes it is desired to describe.

In Fig. 1 the critical range is represented as covering a temperature zone extending from 700° to 800° C. It will not be necessary, for the aim in view, to take into consideration the existence of two critical points, $A_{3.2}$ and A_1 , within that range, nor the fact that the points on heating, $Ac_{3.2}$ and Ac_1 , occur at

FIG. 1.



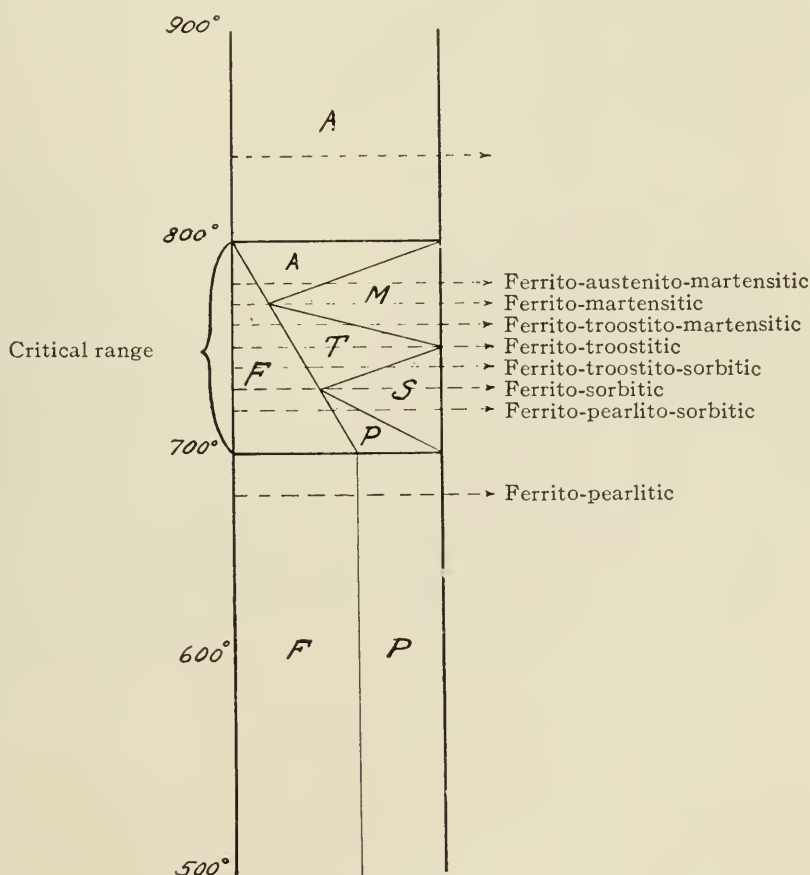
A—Austenite. M—Martensite. T—Troostite. S—Sorbite. P—Pearlite. F—Ferrite.

temperatures some 25 to 50 degrees higher than the corresponding points on cooling, $Ar_{3.2}$ and Ar_1 .

Above its critical range the steel we are studying consists, like all steels, of a solid solution of iron and carbon. In this condition the two constituents are so completely merged that their independent existence cannot be recognized by any physical means; they form a chemically and physically homogeneous mass. Whether carbon in its elemental condition is dissolved in the iron, or whether it is the carbide of iron, Fe_3C , which the iron holds in solution, is here immaterial. We may likewise ignore the various allotropic conditions assumed by iron. The solid solution of iron and carbon stable above the critical range is called "austenite." Whenever it is possible to preserve austenite in the cold to the exclusion of other constituents and to

microscopically examine its structure, it is found to be made up of crystalline polyhedra or grains exhibiting in a polished section the appearance of a network, the meshes representing sections through as many grains, and the net itself, junction lines between adjacent grains (see Fig. 3). The size of the austenite grains increases with (1) the maximum temperature from which cooling starts, (2) the length of time during which the metal was kept at that temperature, and (3) the slowness

FIG. 2.

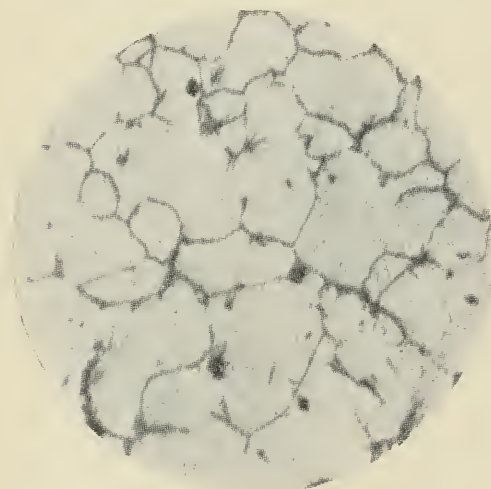


of its cooling to the critical range. It will not be necessary, nor is it desirable, to further discuss here the probable crystallography of austenite. As to its physical properties, austenite is hard, tenacious, and ductile, but has a low elastic limit.

On slow cooling through the critical range, as shown in Fig. 1, Diagram I, the solid solution of iron and carbon is converted into a mechanical mixture or aggregate of ferrite and pearlite, the latter constituent itself being an aggregate, in definite proportion,

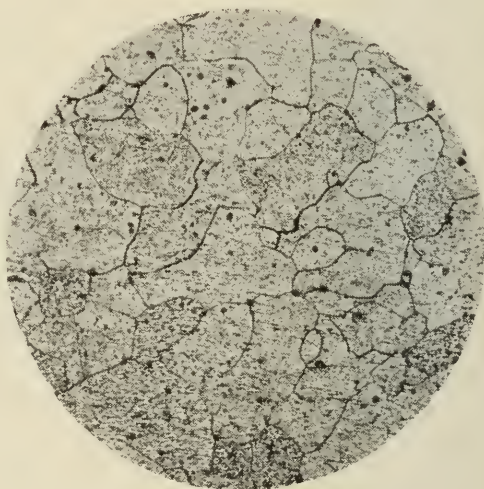
of "ferrite" and the carbide Fe_3C , or "cementite." Ferrite and pearlite may be considered as representing the proximate structural composition of the steel, while ferrite and cementite are its ultimate structural constituents. The structures of ferrite and pearlite are shown respectively in Figs. 4 and 5. It will be noticed that ferrite, like austenite, and, for that matter, like pure metals and solid solutions in general, is made up of polyhedric crystalline grains, giving rise, on sectional polishing, to network structures. Pearlite is built up after the pattern so characteristic of eutectic and eutectoid alloys, of parallel, alternate plates of its two components, namely, ferrite and cementite. These plates are so thin, however, that a magnification exceeding 200 diame-

FIG. 3.



Austenite. (Magnified 100 diameters.)

FIG. 4.



Ferrite. (Magnified 100 diameters.)

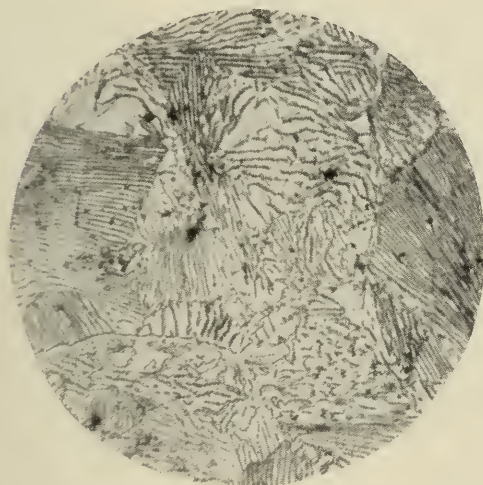
ters is generally required for their resolution. Ferrite is very soft and very ductile, but relatively weak, while pearlite is very tenacious and much harder, but also much less ductile.

It is seen that in cooling through its critical range steel undergoes deep structural changes, being converted from the state of a solid solution to that of an aggregate of varying coarseness. So great a transformation must be accompanied by no less momentous alteration of properties, and, indeed, there is little in common between the physical properties of austenite and those pertaining to the ferrite-pearlitic structure existing below the critical range.

Steel with 0.30 per cent. carbon is composed, after slow

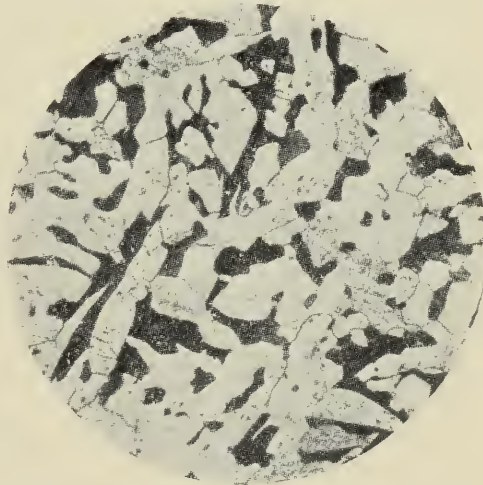
cooling through its critical range, of 64 per cent. ferrite and 36 per cent. pearlite, as graphically shown in Fig. 1, Diagram I. Its structure is illustrated in Fig. 6. Bearing in mind the physical properties of its two components, ferrite and pearlite, it will be obvious that mild steel in its ferrito-pearlitic condition, while more tenacious and less ductile than ferrite, will be considerably less tenacious and more ductile than pearlite. Its tenacity, as a matter of fact, should be in the vicinity of 70,000 pounds per square inch, and its elongation in 2 inches should be about 20 per cent. These properties, moreover, will vary considerably in accordance with the coarseness or fineness of the ferrito-pearlitic structure, the finer structure being generally the

FIG. 5.



Pearlite. (Magnified 500 diameters.)

FIG. 6.



Mild steel (0.30% C.). Ferrito-pearlitic structure. (Magnified 100 diameters.)

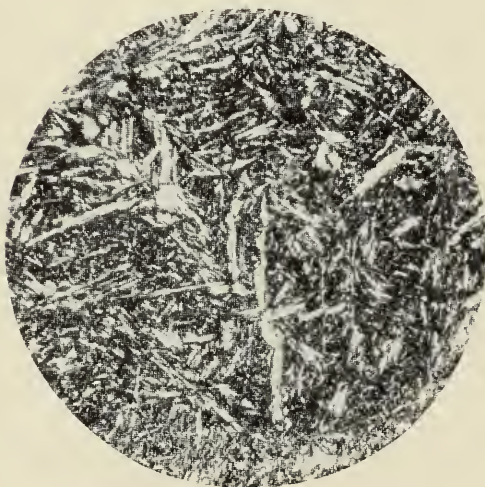
more ductile. The structure of the steel, after slow cooling through the critical range, will, as a rule, be the coarser, the coarser the austenite immediately before its transformation, and this in turn, as already noted, depends chiefly upon the maximum temperature from which cooling started, the time the metal was kept at that temperature, and the rate of cooling.

It should be borne in mind that the ferrito-pearlitic structure just mentioned, and which corresponds to the end products of the structural transformation taking place within the critical range, results from *slow* cooling through that range, as, for instance, in allowing the piece to cool within the furnace in which it was heated. On hastening the cooling, structural conditions may be

produced corresponding to widely different properties, as will now be described.

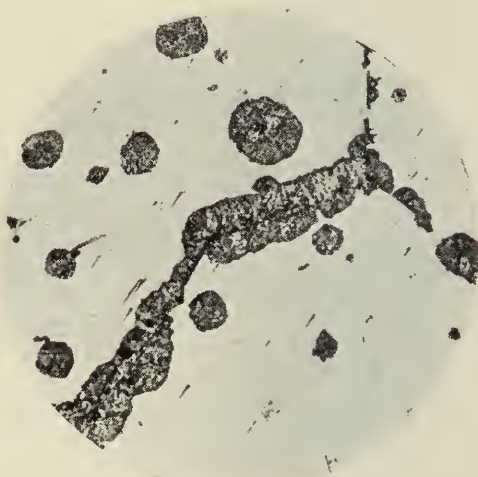
The transformation of the austenitic solution into a ferrito-pearlitic aggregation is not sudden, but, on the contrary, covers a notable range of temperature, while transition constituents are formed within the critical range, as depicted in Figs. 1 and 2. It is intended to show, by means of these diagrams, that, on entering the critical range, the austenite existing above that range is *gradually* converted into "martensite" with rejection of ferrite, a rejection which continues all through the range; that the martensite, on further cooling, is, in turn, transformed into troostite, which, at a still lower temperature, is itself converted into sorbite;

FIG. 7.



Martensite. (Magnified 100 diameters.)

FIG. 8.



Troostite and martensite. (Magnified 100 diameters.)

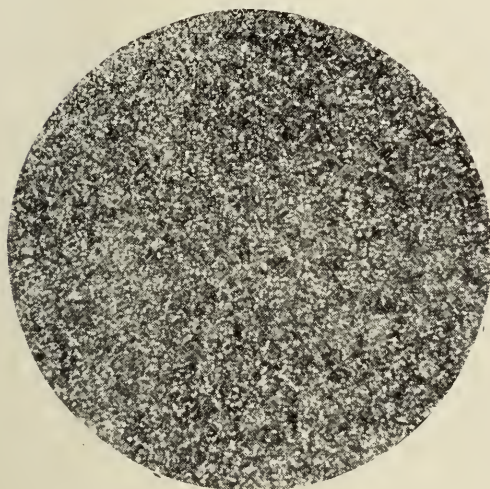
while, finally, pearlite, the end product, forms as the steel emerges from its range. We thus recognize the existence of three so-called transition constituents,—martensite, troostite, and sorbite,—but it will be unnecessary to enter here into a discussion of their probable nature, a subject which is still, to a certain extent, a controversial matter. The structure of these constituents is illustrated in Figs. 7, 8, and 9. Martensite appears to be made up of needles, often forming equilateral triangles; troostite, which in Fig. 8 is seen associated with martensite, consists of irregular ragged or rounded masses; while sorbite exhibits a finely granular and rather indistinct structure. In regard to physical properties, martensite is very hard and brittle, troostite

less hard and less brittle than martensite, while sorbite is less hard than troostite and more tenacious, but less ductile than pearlite.

By referring to Fig. 2 it will be seen that, theoretically at least, seven different structural conditions may be conceived to exist momentarily as the steel undergoes its critical transformation; namely, ferrito-austenitic, ferrito-martensitic, ferrito-troostitic, ferrito-troostitic, ferrito-troostitic-sorbite, ferrito-sorbite, and ferrito-pearlitic-sorbite.

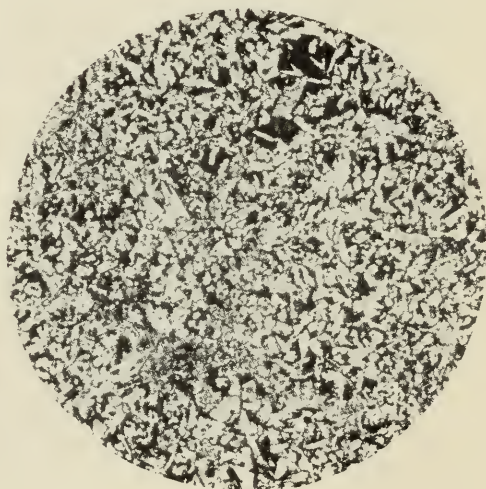
The mechanism of the structural changes depicted in Fig. 1, Diagram I, and in Fig. 2, refer to the changes taking place when

FIG. 9.



Sorbite. (Magnified 100 diameters.)

FIG. 10.

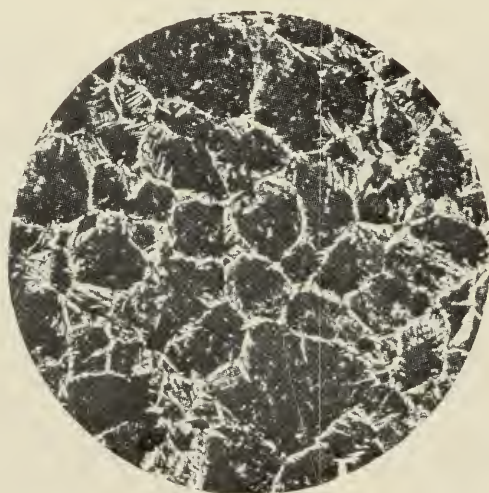


Mild steel (0.30% C.). Ferrito-sorbite structure. (Magnified 100 diameters.)

the cooling is slow enough to permit a complete transformation of the metal with final production of a ferrito-pearlitic structure. It will now be shown that through properly regulated cooling the transformation may be arrested at any desired stage in accordance with the physical properties wanted, which may vary from the hardness and brittleness of the quenched metal to the great softness and ductility resulting from very slow cooling. Between these two extreme types lies a great variety of combinations of hardness, strength, and ductility, each set corresponding to a well-defined treatment; hence the science and art of the heat treatment of steel, the importance of which steel makers and users are only now beginning to fully appreciate.

In Fig. 1, Diagram II, the cooling has been so hastened that on reaching the bottom of the critical range the sorbite had been but partially converted into pearlite, the necessary time for its complete transformation having been denied. This quicker cooling has also prevented a full separation of the ferrite, as indicated in the diagram. The resulting structure may be described as ferrito-sorbite-pearlitic. Large pieces cooled in air often acquire it. Obviously, because of the properties of sorbite, steel in this condition is more tenacious, but less ductile, than the same metal in its ferrito-sorbite state.

FIG. 11.



Mild steel (0.20% C.). Ferrito-sorbite-pearlitic structure. (Magnified 100 diameters.)

In Fig. 1, Diagram III, is represented the mechanism by which we can conceive the production of sorbite to the exclusion of pearlite, owing to relatively rapid cooling in passing through the critical range. The steel is now ferrito-sorbite, while the amount of ferrite it contains is but half the amount of that constituent present in the ferrito-pearlitic metal (Fig. 1, Diagram I), the necessary time for its complete separation having been denied. In its ferrito-sorbite condition the steel is decidedly more tenacious, but less ductile, than when ferrito-pearlitic. It is also harder, has a higher elastic limit, and is in a better condition to resist shocks and alternate stresses. A ferrito-sorbite structure is readily produced in allowing small pieces to cool in air, or

larger ones in oil.¹ Fig. 10 shows the structure of mild steel when ferrito-sorbitic.

In Fig. 1, Diagram IV, the cooling has been so rapid that, on emerging from its critical range, the metal is caught in a

FIG. 12.



Various structures of mild steel (0.30% C.).

- | | |
|---|---|
| 1. Steel as cast. | 9-13. Heated above critical range, followed by cooling in air or oil, or heated above critical range, cooled in water or oil and reheated to 600° C. Ferrito-sorbitic or ferrito-sorbito-troostitic structures. |
| 2. Steel cast and imperfectly annealed (remnants of ingotism). | 14. Forged and finished at low temperatures. |
| 3. Steel cast and properly annealed. | 15. Forged and finished at high temperatures. |
| 4-8. Heated to various temperatures above critical range for various lengths of time and slowly cooled in furnace. Ferrito-pearlitic structures of different degrees of coarseness. | 16. Cold worked. |

ferrito-troostito-sorbitic state, only a small amount of ferrite, moreover, being present. The metal is now harder and has lost

¹ It may also be obtained by quenching the metal from above its critical range in water or oil, thereby securing a fine structure, followed by reheating to some 600° C. to cause the transformation into fine sorbite of any existing troostite or martensite.

much of its ductility because of the presence of troostite. This structure may be produced by quenching small pieces in oil, or larger ones in water, or by a suitable tempering of hardened pieces. The structure of mild steel containing ferrite, troostite, and sorbite is shown in Fig. 11.

In Fig. 1, Diagram V, the steel has been cooled so quickly that some martensite, as well as troostite, remains undecomposed on reaching the bottom of the critical range, while but a very small amount of ferrite has had time to separate. In this ferrite-troostite-martensitic condition the metal is hard and deficient in ductility. A structure of this type may be produced by quenching small pieces in water.

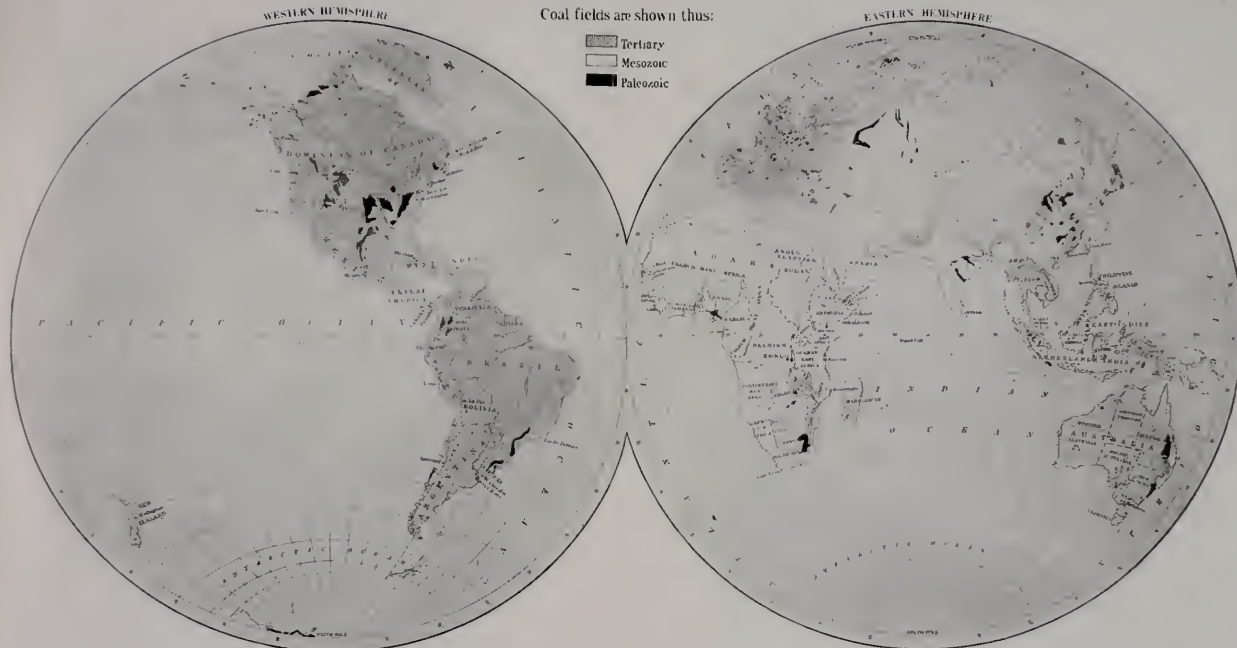
The retention of martensite to the exclusion of troostite, and, *a fortiori*, the retention of austenite, is quite impossible in mild steel. While martensitic structures, moreover, are those needed in high carbon steel for the production of cutting tools, for instance, they are never wanted in low carbon steel, the structures depicted in Fig. 1, Diagrams I, II, and III, being the only ones of interest to the users of such steel.

Fig. 12 is a composite photo-micrograph showing the various types of structure mild steel may be made to acquire. The legend makes it self-explanatory.

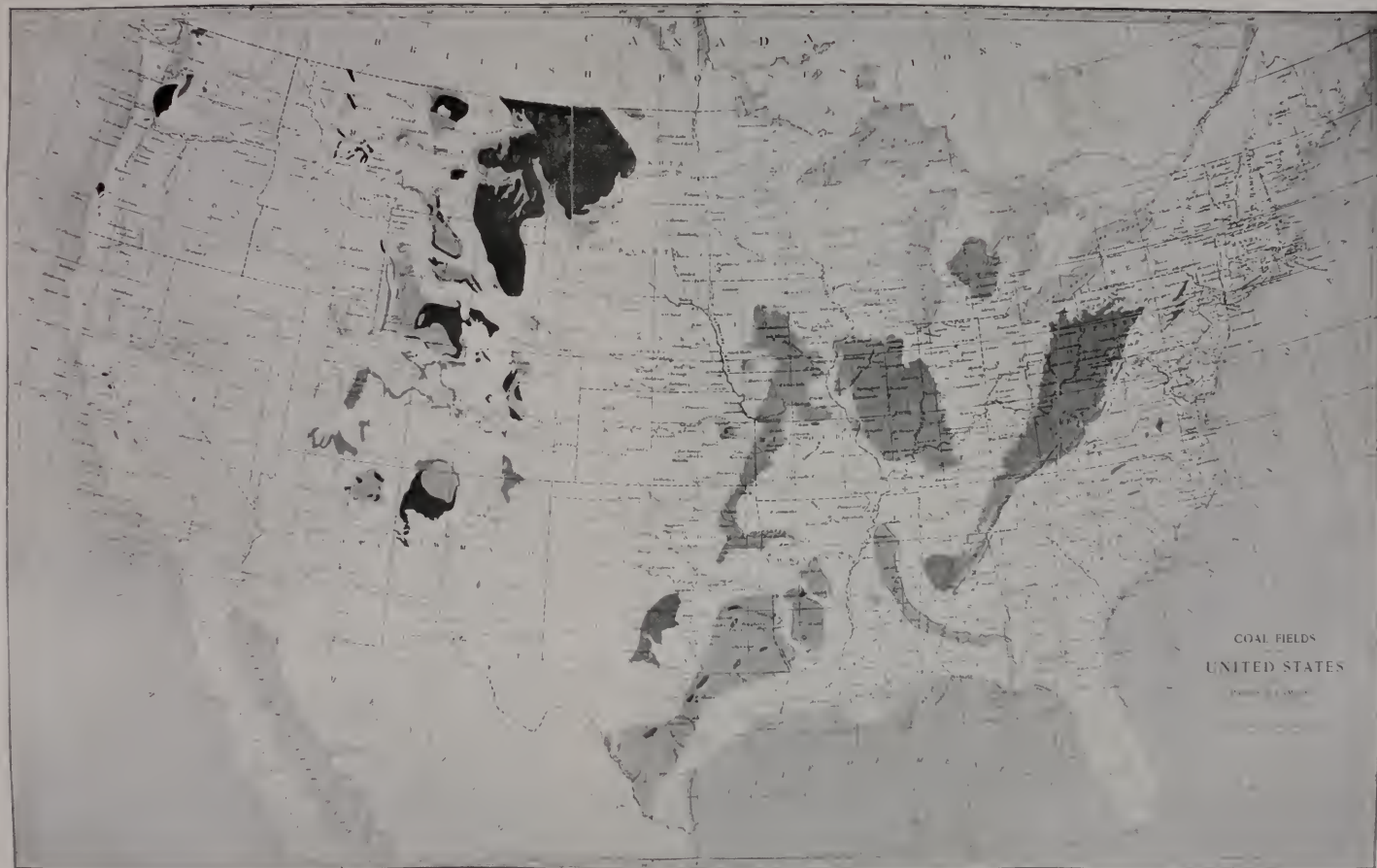
The Colloidal Nature of Caoutchouc. A. WAGNER. (*Chem. Zeit.*, xxxvi, 833.)—Ahrens's statement that the so-called Para-spots in pure vulcanized mixtures consist of an organic substance and not of crystallized sulphur is shown to be erroneous by the following experiment. When a thin section of pure vulcanized rubber is placed together with a solvent, such as benzol, between two glasses and examined under a microscope of comparatively low magnification, ramified, arborescent forms are seen, which are composed of small crystals; there are also present small, round, floating bodies, which prove to be amorphous sulphur. After a short time this sulphur dissolves, and the spherical bodies as well as the arborescent forms gradually disappear; with carbon bisulphide as a solvent, solution is more rapid. This solution is clear except small fragments of foreign matter (filling, etc.). Thus the theory of the network structure of albuminoid compounds or of polymerized or oxidized rubber in vulcanized rubber appears untenable. Further proof of this is given by the fact that when vulcanized rubber containing no free sulphur is examined as above, the structure described is not visible—at any rate, not under such low magnification as is necessary for the identification of the different crystalline forms of free sulphur in rubber.

J. F. L. May, 1914.

COAL AND ITS BY-PRODUCTS.



Coal fields of the world.



BITUMINOUS AND ANTHRACITE COAL
includes anthracite coal - caking coal

SUBBITUMINOUS COAL

LIGNITE



Areas containing workable coal beds



Areas that may contain workable coal beds



Areas probably containing workable coal beds



Areas containing workable coal beds



Areas that may contain workable coal beds



Areas probably containing workable coal beds



Areas containing workable lignite beds



Areas that may contain workable lignite beds

COAL AND ITS BY-PRODUCTS.*

BY

LOUIS CLEVELAND JONES, Ph.D.,

Chief Chemist, The Solvay Process Company, Syracuse, N. Y.

THERE have been listed and described perhaps several hundred thousand organic compounds, practically all of which can be obtained directly or indirectly from the decomposition of coal by heat.

Carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, and the halogens are normal constituents of ordinary coal, so that all compounds containing any or all of these substances, in any proportion, are possible direct by-products of coal. Coal also at times contains unusual constituents such as the rare elements in the ash, even gold and radium. We have known a coal ash to contain so much gold that the possibility was considered of treating its ash after burning, as a gold ore. There are seams of coal in southern Indiana and eastern Kentucky which contain iron ore. The ash of some coals in eastern Pennsylvania and eastern Kentucky makes an excellent high grade refractory fire-clay. One of the principal coal seams in Illinois consists of an upper bench of limestone.

But the true by-products of coal are the organic products, and they are so numerous that it would weary you to mention even all their group names. Acid bases, alkaloids, alcohols, gums, varnishes, solvents, sugars, saccharine, and stuffs as bitter as saccharine is sweet; disinfectants, dye stuffs of brilliant hues, stimulating or sleep-producing drugs, healing medicines and violent poisons, vile odors and pleasing perfumes, are all by-products from the carbonization of coal.

But I must not weary you with the recital of these products and their nature, for I wish to consider the nature of coal itself.

In order more clearly to understand what coal is, we must look into its origin.

* Presented at the meeting of the Section of Physics and Chemistry, held Thursday, March 5, 1914.

EARLY ATMOSPHERE OF THE EARTH.

A generation ago it was not good science to talk much about transmutation. However, after the recent accomplishments of Madam Currie, Sir William Crooks, Professor Rutherford, and others, transmutation has been brought again into the realm of science.

FIG. 1.



Railroad tunnel piercing nearly vertical layer of Lee conglomerate near Big Stone Gap, Virginia.

After the primordial substance had been transmuted into some eighty present well-known elements, and these were still in the condition of vapor uncondensed, there was present, fortunately, sufficient oxygen to combine with all the other elements which cared to associate with it, and just a little more. These vapors cooled and condensed to a molten mass in the form of a sphere—our earth. 45 per cent. of the earth's crust, say one-quarter of the whole weight of this sphere—the earth—is represented by the oxygen which has combined with other elements to form rocks and water. One-quarter of the weight of the earth

represents 32 billion trillion tons of oxygen, and there was left over uncombined in our atmosphere 670 trillion tons, or only two-millionths of one per cent. of the total. So you see that it is by a rather close margin that we now have enough oxygen in our air to enable human beings to live.

The earth, now cooled to the condition of a fairly homogeneous fused mass of rocks, may be compared with a tank of

FIG. 2.



Typical scene in Letcher County, Kentucky, showing log cabin and path leading to coal opening in the mountain side.

fluid melted glass, composed of impure mixed silicates with an excess of silica, about 75 per cent. of the total weight of the earth's crust, while the mixture in an ordinary glass furnace contains also about the same percentage (70 to 75 per cent.) of silica.

Above this fused mass was an atmosphere containing the present amount of air (nitrogen and oxygen), and also as steam all the water now condensed in the ocean, and all the carbon dioxide now fixed in the form of limestone (calcium carbonate).

There was also present, of course, in that atmosphere relatively small amounts of sulphur and halogens, since deposited as salts.

A rough estimate indicates that the total amount of water now in the world, if evenly distributed, would cover all the earth's surface 10,000 feet deep (say 3000 M.).¹ Likewise the limestone deposits of the earth's surface are, on an average, 6000 feet (say 1800 M.) deep.

On this basis, then, and since one atmosphere equals 10 tons per M² of surface, we can readily calculate that, with all the water as vapor, and all the carbon dioxide as gas in the atmosphere, the pressure upon the earth's surface would be enormous, *i.e.*:

- ± 300 atmospheres water vapor.
- 200 atmospheres carbon dioxide.
- 1 atmosphere nitrogen and oxygen.

Thus the earth's atmosphere was composed, by volume, of

	<i>Per cent.</i>
Steam	79.2
Carbon dioxide gas	20.4
Air (oxygen and nitrogen).....	.35

all under a pressure of say 500 atmospheres or 7350 pounds per square inch. Under these conditions cooling was rapid, due to the continuous condensation of water vapor high in the atmosphere, and its re-evaporation lower down.

When the earth's crust became sufficiently cool the solid granite masses, thrust up by contraction, were violently attacked by this superheated steam and carbon dioxide under tremendous pressure. Decomposition of the granite was rapid, with formation of shales (aluminum silicates) and bases (alkalies and alkaline earths) from feldspars, and sandstones (silica) from quartz. Cooling continued below the boiling-point of water so that most of the water condensed, leaving a moist atmosphere containing principally CO₂, *i.e.*, over 98 per cent. of CO₂, and less than 2 per cent. of nitrogen and oxygen together.

In these warm waters shales and sandstones were sedimented,

¹ Calculated from average depth of oceans as determined by measured speed of volcanic tidal waves crossing the Pacific.

and at the same time lime from the decomposed granites was carbonated or bicarbonated and deposited to form the enormous limestone beds of the geologic ages preceding the coal-forming era.

Since our limestone deposits are generally sedimentary it is evident that much water had condensed before the great bulk of the carbon dioxide was taken from the air by the decomposing granites. At any rate, in this manner, at the same time water was condensed, or subsequently, the formation of limestone (possibly, as Dana says, by means of animal or vegetable organisms), with absorption of carbon dioxide, continued until, with decreased temperature and decreased amounts of carbon dioxide in the air, plant and animal life became possible. Experiments indicate that plants of our time will not thrive in an atmosphere containing more than 10 per cent. of carbon dioxide, but that they do benefit considerably by percentages higher than normally present in our air. Certainly in the carboniferous era plant life flourished as never before or since, due to a warm, moist climate, and probably also to high atmospheric pressure, and particularly in the presence of a moderately high percentage of carbon dioxide. Possibly also the highly carbonated earth waters, as recent experiments suggest, stimulated a luxuriant growth of vegetation.

AMOUNT OF CARBON DIOXIDE IN THE ATMOSPHERE IN COAL ERA.

The ratio of the thickness of limestone beds deposited before the beginning of the coal-forming era, to the limestone formed from granite decomposed since, would permit us to calculate what amount of the 98 per cent. of carbon dioxide originally present remained in the atmosphere when our coal beds were formed. Such estimates are extremely indefinite, but it is quite probable that the atmosphere of the coal-forming era contained from 2 to 5 per cent. of carbon dioxide, while at present, as we know, we have but .03 of one per cent. Furthermore, this carbon dioxide and high moisture content of the air doubtless brought about a more uniform distribution of heat, so that at any rate tropic vegetation flourished from the equator to the poles.

In addition to the absorption of carbon dioxide during and

since carboniferous times to form limestones, the great coal deposits of the world have taken their carbon equivalent from the carbon dioxide of the atmosphere.

CO₂ REQUIRED TO FORM COAL.

A committee of the XII International Geological Congress, held in Canada last fall, determined the total mineable coal de-

FIG. 3.



The thickest opening in Elkhorn Seam, Letcher County, eastern Kentucky. The horse is standing on a level with the bottom of the coal seam.

posits of the world to be at most 7400 billion tons. Double this, or 14,800 billion tons, may be taken to safely represent all other coal in thin seams beneath the ocean and in other ways not mineable.

Now, if we compare our total coal deposits, 15,000 billion tons (calculated into its equivalent of carbon) with the .03 per cent. of carbon dioxide still in our atmosphere (equivalent to 700 billion tons of carbon), we get the striking information that the coal deposits of the world required and took from the

air 11,000 billion tons of carbon for their production, and there are left in the air to-day but 700 billion tons of carbon, or but 6 per cent. of the total originally required to produce the coal we have. In other words, no more coal could have been deposited because the raw material was practically used up. This world cannot, therefore, have another carboniferous era until we burn up our present deposits, and when we do get them

FIG. 4.



Bucket cable line bringing coal across a valley in eastern Pennsylvania.

burned up there will be say .6 per cent. more CO_2 in the atmosphere, and the same amount less of oxygen than at present.²

FLUCTUATIONS OF CARBON DIOXIDE IN THE ATMOSPHERE.

How much carbon dioxide has been absorbed by granites decomposed since the beginning of the carboniferous age is not readily determined, but the larger amount present at that time,

² Sir William Herschel calculated the total weight of the earth's atmosphere as $11\frac{2}{3}$ billion tons. It is really $11\frac{2}{3}$ quintillion pounds or 5,800 trillion tons, five hundred times Sir William's figure.

besides directly giving richer food to plant life, has been considered sufficient to so modify climate as to account for the tropical conditions prevalent at that time.

Arrhenius and Chamberlain have attempted to explain the known fluctuations of climate as indicated by glaciation by corresponding fluctuations in the carbon dioxide of the atmosphere. But a sufficient cause for such changes in the amount of carbon dioxide is hard to find. We may estimate the earth's water to contain perhaps seven parts carbon dioxide per one hundred thousand, in the form of bicarbonates, more than sufficient if transferred to the atmosphere to supply carbon for another coal-forming epoch, but boiling would be required to drive it into the atmosphere.

The decomposition of a small portion of the limestone, by heat or otherwise, would, of course, return the requisite amount of carbon dioxide to the air to give again to earth universal tropical conditions. Without heat, however, any acid would be required to evolve carbon dioxide, but no such acid suggests itself other than a rather improbable one, *i.e.*, nitric acid formed by oxidation of nitrogen by electrical discharges which the earth in its history may have developed or encountered.

AMOUNT OF CARBON DIOXIDE NOW IN ATMOSPHERE CONSTANT.

It would not be unreasonable to estimate that the ordinary growth of vegetation and forestry may consume 400 grams of carbon dioxide per square meter of surface per year, or 100 grams per square meter over the entire surface of the earth, or about 2 per cent. of the 4400 grams of CO_2 in our present atmosphere. The production of carbon dioxide by the 1200 million tons coal annually consumed is but one-seven-hundreth part of the carbon dioxide already in the air. At any rate the present increase or decrease of the carbon dioxide in the air is not perceptible by present means of analysis. Any further decomposition of granities, though now slow, due to the comparative small amount of the rock exposed, must absorb a corresponding amount of carbon dioxide from the air, and when the minutest amount more has been absorbed, compared with what has already been accomplished by such decomposed granite, no more carbon dioxide will remain to sustain plant life and the earth will become a dead world. But granites, besides being

protected (covered up) from weathering, are also decomposing more slowly because of the comparatively low temperature and low pressure of the atmosphere acting upon them. Since observations have been made, no diminution of the carbon dioxide in the atmosphere has been observed.

MINEABLE COAL RESOURCES OF THE WORLD.

In the following table are given the coal resources of the world, and on this basis it will not be difficult to predict great commercial growth in such nations as China, when once she has had a generation of technical education.

The present production, however, of coal in China, as given for 1910, is only a little over one-half that of Belgium.

COAL RESOURCES OF THE NATIONS OF THE WORLD. (In million tons.)

[From data in report of committee of XII International Congress of Geology, Canada, 1913.]

Nation.	Anthracite.	Bituminous.	Sub-bituminous.	Total.
United States.....	19,684	1,955,521	1,863,452	3,838,657
North America (except United States)	2,158	284,162	948,454	1,234,774
China.....	387,464	607,523	600	995,587
Germany.....	.....	409,975	13,381	423,356
Asia (except China).	20,173	152,575	111,251	283,999
Great Britain and Ireland.....	11,357	178,176	.....	189,533
Oceania.....	659	133,481	36,270	170,410
Europe (except Germany, France and Great Britain and Ireland.....	39,718	92,331	21,669	153,718
Africa.....	11,662	45,123	1,054	57,839
South America.....	700	31,397	.....	32,097
Total.....	496,846	3,902,944	2,997,763	7,397,553

(Note enormous deposits of anthracite in China.)

From the following table showing the annual coal production of the principal countries of the world, and the table calculated from it showing the percentage increase in production by five-year periods, we are able to predict with some degree of certainty a comparatively early exhaustion of the coal resources of the world. The incomplete data for the years succeeding 1910

TABLE OF THE ANNUAL COAL PRODUCTION OF PRINCIPAL COUNTRIES OF THE WORLD. (In million tons.)
[From Report of XII International Geological Congress, 1913.]

Country.	1865.	1870.	1875.	1880.	1885.	1890.	1895.	1900.	1905.	1910.
Australia.....	.....	.....	.....	.....	.....	.....	4.01	6.48	6.83	10.00
New Zealand.....	.....	.....	.....	.....	.....	.....	0.76	1.11	1.41	2.23
China.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.59
India.....	.....	.....	.....	.....	.....	.....	2.65	6.22	7.92	12.09
Japan.....	.....	.....	.....	.....	.....	.....	4.84	7.43	11.89	14.79
South Africa.....	.....	.....	.....	.....	.....	.....	1.40	0.76	3.22	5.50
Canada.....	.....	.....	.....	.....	.....	.....	3.19	5.09	7.96	13.01
United States.....	24.79	29.95	48.20	66.83	102.18	141.62	177.59	243.41	351.12	445.81
Mexico.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.45
Great Britain.....	99.76	112.24	135.49	149.38	161.96	184.59	194.35	228.77	239.89	264.50
Spain.....	0.45	0.66	0.61	0.85	0.94	1.18	1.77	2.58	3.20	3.55
France.....	11.84	13.30	16.95	19.36	19.51	26.08	28.24	33.40	36.05	38.57
Belgium.....	11.84	13.69	15.01	16.88	17.44	20.37	20.41	23.46	21.84	23.13
Germany.....	28.33	34.88	48.53	59.12	73.67	89.29	103.96	149.79	173.66	221.98
Austro-Hungary.....	2.03	8.36	13.06	14.80	20.43	26.10	27.25	39.03	40.72	38.00
Italy.....	.....	.....	.....	.....	.....	.....	0.25	0.48	0.31	0.40
Sweden.....	.....	.....	.....	.....	.....	.....	0.20	0.25	0.33	0.21
Russia.....	0.33	0.69	1.17	3.27	4.24	7.00	9.10	14.76	17.12	24.57
Other countries.....	2.71	4.04	6.26	9.28	12.45	16.89	1.75	2.90	4.55	8.00
Total.....	182.08	217.81	285.30	339.37	412.82	513.12	581.72	765.92	928.02	1,143.38

show no falling off in this production of coal, but, in fact, it is already evident that the normal five-year increase will be exceeded by 1915.

INCREASE IN COAL PRODUCTION BY FIVE-YEAR PERIODS FROM
1865 TO 1910.

Percentage increase over previous period.

	1865 to 1870.	1870 to 1875.	1875 to 1880.	1880 to 1885.	1885 to 1890.	1890 to 1895.	1895 to 1900.	1900 to 1905.	1905 to 1910.	Average.
United States	21	61	38.5	53.0	38.0	26.0	37.0	44.0	27.0	38.4
World	19	14	19.0	21.5	24.3	13.3	31.6	21.3	23.3	20.8

Thus coal production of the world doubles every 20 years and of the United States doubles every 11 years.

On this basis the world's resources will last 250 years, while the United States at her higher increase in production would exhaust her own enormous supply in 110 years.

Furthermore, if we purchase coal lands now in the United States at present values, say 2 cents per ton in the ground, and charge against this investment compound interest at 6 per cent., such unused coal as we may have unmined at the end of 120 years will have cost us \$20 per ton, or say f.o.b. cars \$21, the same figure that White & Hazard paid for coal 100 years ago. Two cent coal carried under the same conditions 250 years would cost about \$40,000 per ton. So we see that it is practically immaterial to our posterity whether any coal lasts 250 years or not. Its price would be prohibitive, but of course prohibitive prices can never be maintained.

COALS ARE RESIDUES OF CARBONIFEROUS VEGETATION.

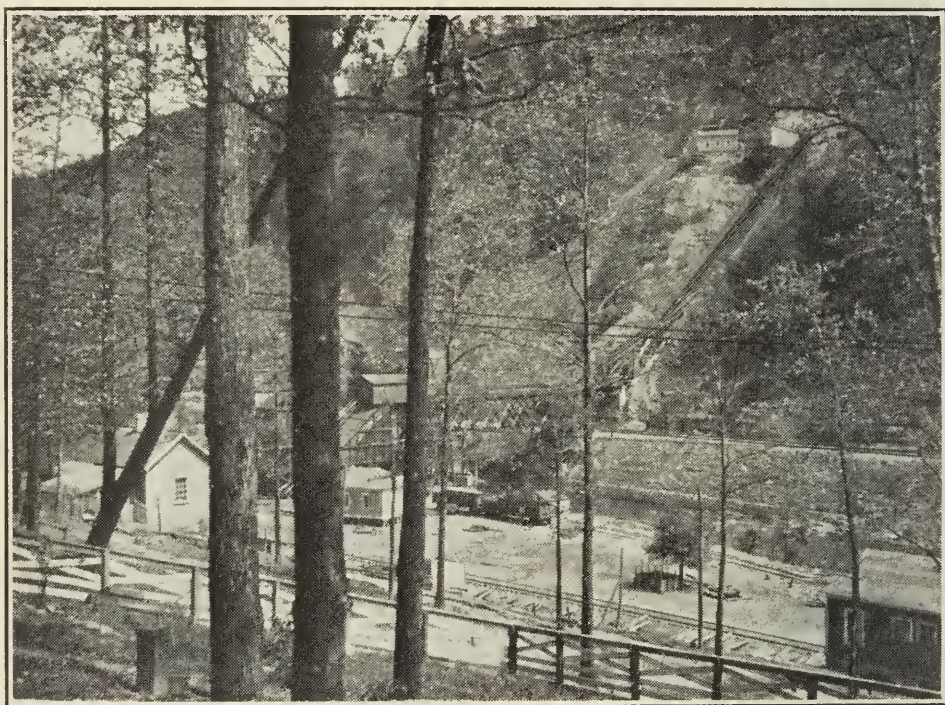
Now, we have 7400 billion tons mineable coal, but of greatly different varieties. And though capable of producing an enormous number of by-products, the substance of the different coals is not so mysterious if we remember that each variety of coal represents only a different step in nature's slow process of converting the vegetation of the carboniferous era into the fuels so necessary to our modern civilization.

Essentially, therefore, coal was originally wood (cellulose $(C_6H_{10}O_5)_n$ and resins, now converted in the age long processes

of nature into peat, lignite, semi-bituminous, bituminous, gas coal, smokeless coal, semi-anthracite, anthracite, graphite, diamond, and we might also place carbon dioxide, the raw material from which wood is made, at the head of the series.

It is thus quite remarkable that our fuel coals, near the end of the series, upon burning return again to the air as carbon dioxide, to be converted by photo-chemical processes a second time into vegetation (wood), and thus repeat the cycle of the

FIG. 5.



Typical drift mine in Tug River district, West Virginia.

carboniferous age. But geological ages are made up of cycles of incomprehensible lengths of time. So here when we seek the origin of graphite which is found in the granites of the archaic ages, we can only answer, a previous carboniferous era.

This series of products, with the geological and paleobotanical evidences of its succession, is so reasonable that there can be little doubt that it accurately represents ancient vegetation in the different stages of carbonization in nature's by-product retort.

The earth's crust is such a retort, and the by-products have

been saved in the form of asphalt, bitumen, petroleum and natural gas.

We may estimate that over 70 per cent. of the weight of wood is lost in being converted to coal, and, according to tests given below, possibly one-half of this loss was carbon dioxide and the other half combustible gas and oils. This oil and gas, nature's by-products, stored beneath folds of rock strata, constitute our present sources of petroleum and natural gas.

NATURAL BY-PRODUCTS OF CARBONIZING ANCIENT VEGETATION RESIDUES.

Since commercial carbonizing of coal gives the benzene series of products, and not paraffines as existing in petroleum and natural gas, efforts have been made to explain the origin of natural gas and petroleum from animal remains, and Moissan has suggested the carbide theory. We believe, however, that the slow distillation of coal at low temperatures is a more logical explanation.³

Industrial experiments recently carried on in England upon low temperature distillation by the Coalite process, and more recently on coking coals at even lower temperatures, and *in vacuo*,⁴ indicate that petroleum products identical with those found in nature are thus obtained.

In duplicating nature's conversion of bituminous coals to anthracite, the modern by-product oven, operating at a temperature of 1000° C. or more, does the work of ages in a day, producing coke the equivalent of natural anthracite, and, in place of natural gas and petroleum, illuminating gas and oils of the benzene series.

In the electric furnace we convert coke into graphite and Moissan has converted graphite dissolved in cast iron into the diamond, the end of the series. But at these high temperatures, as stated before, the by-products are largely of the benzene series, while nature's by-products are of the methane series.

³ Mabery's study of "Mahone Petroleum, its Recent Origin and the Origin of Petroleum in General," has just come to my attention. The evidence given leaves little doubt that petroleum is one of nature's by-products of coal.—J. I. and Eng. Chem., Feb. 14, p. 101.

⁴ Pictet & Bouvier, Ber., 1913, p. 3342.

LOW TEMPERATURE CARBONIZING EXPERIMENTS.

Recently, therefore, in our laboratory at Syracuse, we have tried to determine the nature of the products at low temperatures, starting with the wood and going through the series to coke.

Our experiments are still incomplete, but some of the results are tabulated below. For example, wood, brown lignite, black lignite, Illinois coal, Kanawha gas coal, smokeless coal and anthracite were gradually heated until decomposition started and a small part of the gas was driven off. The results are calculated to the pure, dry coal basis.

In these experiments we used a cast-iron bomb, heated electrically or in a muffle furnace. This bomb, with absorbing apparatus and gas holder, was devised by the writer about eight years ago, and has been much used in the laboratories of the U. S. Government, and in our laboratories, for determining the nature and amount of products from various coking coals under varying conditions.

	Wood.	Brown lignite.	Black lignite.	Illinois coal.	Kanawha gas.	Smokeless.	Anthracite.
<i>Analyses (%)</i> :							
H ₂ O and volatile	75	70.5	65.6	42.0	29.0	20.0	7.9
Fixed carbon	25	29.5	35.0	58.0	71.0	80.0	92.1
Temp. decomposition (° C.)	150	230	260	300	330	330	340?
Temp. range of expts. (° C.)	150-188	230-320	260-340	300-330	300-360	330-400	230-475
Litres gas evolved from 500 gms. . . .	43.5	10.8	14.0	11.5	14.0	9.3	4.6
Cu. ft. gas per ton. . .	3080	750	1000	815	1000	659	326
<i>Gas analysis (%)</i> :							
CO ₂	58.6	55.6	49.3	24.1	7.3	6.5	10.3
C ₆ H ₆ . . . . .	.5	.6	.9	2.8	.5	2.6	1.3
C ₂ H ₄ . . . . .	.6	1.0	.8	2.2	1.4	2.3	.4
CO	35.0	24.7	19.5	10.6	6.0	4.1	2.6
CH ₄	1.3	11.4	19.5	43.3	57.4	53.5	70.6
H ₂	1.0	.3	.0	3.4	14.6	9.7	.0
N ₂	3.0	6.4	10.0	13.6	12.8	21.3	14.8
Per cent. by weight volatilized.	51.9	26.8	31.0	23.7	12.2	10.0	.7
<i>Analysis of residue</i> :							
Volatile	56.0	39.0	30.8	23.3	18.7	13.9	7.1
Fixed carbon	44.0	61.0	69.2	76.7	81.3	86.1	92.9

The residue from the first carbonizing test on the brown lignite was again heated from 450 to 500° C., producing 3500 cubic feet per ton of gas of analysis as shown under heading "A."

This second residue, heated again to 920° C., gave 7000 cubic feet of gas of analysis under heading "B."

	"A."	"B."
	<i>Per cent.</i>	<i>Per cent.</i>
CO ₂	27.2	7.0
C ₆ H ₆	5.5	1.2
C ₂ H ₄	3.2	1.1
O ₂ .....	.7	.5
CO	9.2	22.5
CH ₄	38.4	18.3
H ₂	12.0	41.8
N ₂	3.8	7.5

Evidently from these tests decomposition gradually brought about by heat tends to drive off at first the high oxygen content, and each coal type is converted into a type similar to, though not exactly like the succeeding higher grade fuel.

In the case of wood, the gas first evolved contains about 97 per cent. of CO₂ and CO. Similarly the lignites and Illinois coals first give off a high percentage of oxygenated compounds, and in this way necessarily the residues contain less oxygen and are of higher calorific value.

Under high pressures doubtless a sharper fractional decomposition would result, and the residues even more closely resemble the natural fuels.

At any rate, such slow, artificial carbonization is strikingly suggestive of nature's process. These residues show decided resemblances to the natural product. That they are not identical, both physically and chemically, may be due to the high pressure used in nature which we have made no effort to duplicate.⁵

⁵ Results obtained by Ralston, U. S. Bureau of Mines, when plotting the composition of coals by the ingenious triangle method, indicate that the curve of decomposition bends strongly as semi-anthracite is approached, corresponding to the bend in our curve for calorific value of volatile matter.

NATURAL GAS A BY-PRODUCT OF COAL.

But if natural gas, chiefly methane and hydrogen, is a by-product of nature's carbonizing processes, we must explain the disappearance of the large amount of carbon dioxide and carbon monoxide which was originally present in such decomposition gases. May we not assume that the CO_2 has been absorbed from the gas by the alkaline earth waters produced by weathering rocks, and that the carbon monoxide has been absorbed and oxidized by metallic oxides?⁶ Gas thus obtained from carbonizing lignite, for example, by removal of CO_2 and CO would be practically identical with natural gas. Thus, calculating out the CO_2 and CO from the gas obtained in heating lignites at low temperatures, we have left a gas containing principally methane, *i.e.*, a typical natural gas.

CLASSIFICATION OF COALS.

Now that we understand the nature of coals as different residues in the progressive decomposition of wood into graphite, we are in a position to classify them. Rejecting accidental impurities, such as ash and sulphur, and using the pure coal basis, coals may be classified in several ways. Five important differences are suggested on the following chart as bases of classification; for example, moisture, volatile, oxygen content, calorific value, and finally initial decomposition temperature. Specific gravity, total carbon, oxygen content, and other characteristics might also be given, all of which indicate the same progressive change in characteristics.

BETTER STANDARDIZED ANALYTICAL METHODS REQUIRED FOR
VOLATILE MATTER AND MOISTURE.

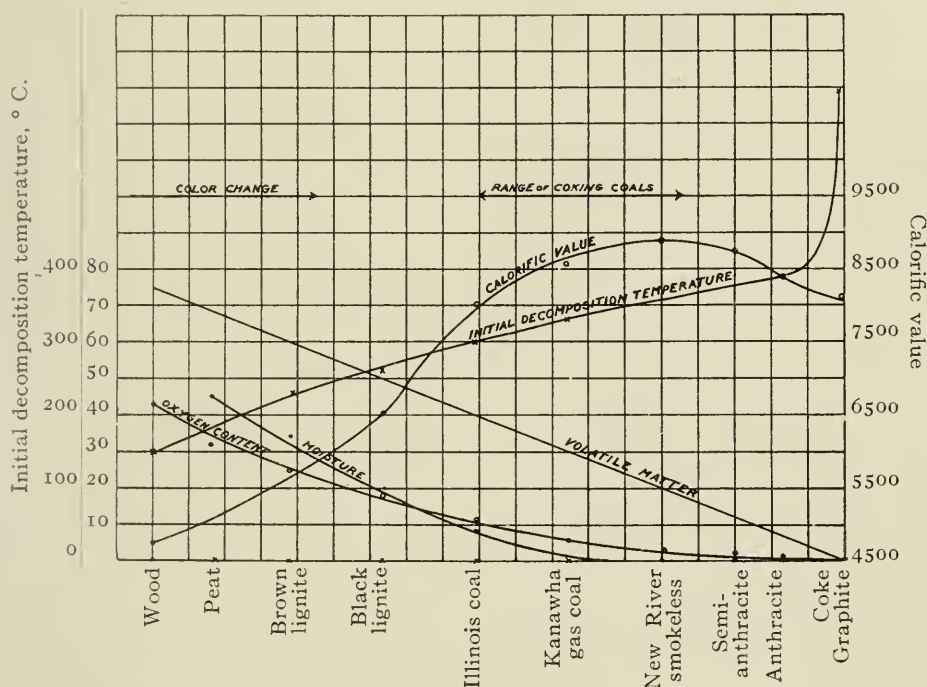
Unfortunately it is necessary to call attention to the lack of uniformity in methods of determining moisture and volatile matter in coals, since much of the data given in the tables pre-

⁶ It is well known that CO in the presence of hydrogen can be oxidized to CO_2 without attacking the hydrogen by passing over metallic oxides. This selective oxidation is possible with ferric oxide and with copper oxide. Temperatures as low as 250° C. are sufficient.

sented depends in particular upon consistent results in the determination of these figures.

An atmosphere standing over a calcium chloride solution containing 35.5 per cent. anhydrous chloride will show a test

CHART VI.



at any ordinary temperature of 50 per cent. relative humidity. Likewise atmosphere in equilibrium with calcium chloride solutions will have the following relative humidities:

Calcium chloride.	Humidity.
Per cent.	Per cent.
26	60
12	40
20	50
30.5	30
35.5	70
41	90
45	80

A coal in such an atmosphere will, like any other hygroscopic material, take up and hold a definite amount of moisture according to its position among the types of fuels shown on the previous chart.

Volatile tests can be made with much satisfaction by use of the Meker burner, but perhaps for strict comparison standardized conditions in a muffle furnace are better.

Evidently as we progress in the series volatile matter, oxygen and moisture go down, while calorific values and temperatures of decomposition go up. As decomposition progresses the specific gravity also goes up.

I am not aware that the decomposition temperatures of coal types have ever before been studied, but since, as we have assumed, coals are residues representing the different steps in nature's carbonizing process under progressively severer conditions, it is only natural that they should have different, and, as we go up the scale, increasing temperatures at which they begin (again) to decompose. That these decomposition temperatures are progressively higher is a further strong indication that coals really are just such residues as has been assumed.

Low grade coals contain much moisture. They are in fact hygroscopic, and will, like other hygroscopic materials, when dried take up again moisture from moist air in proportion to its relative humidity.

As has sometimes been assumed, high volatile coals are not geologically new coals, nor are smokeless coals of an older geological formation, as is evident from the wide variations in volatile found in coals from the same geological seam. For example, the Pocahontas coals vary in volatile from say 16 per cent. in the true Pocahontas district, to above 30 per cent. in the equivalent geological New River district north of Meadow River, W. Va.

Though coals were formed from vegetation at the beginning of the carboniferous era, in the presence of more carbon dioxide in the air than later coals, this does not seem to have been the cause of any real difference in their character.

The classification, however, of coals on the basis of temperature required to decompose, is rational, as is strikingly shown from a study of coal deposits everywhere. In Washington State there are coals of all types from lignite to graphite, and, under different conditions, all types may be found in what appears to be the same geological horizon. When the seam is horizontal the coal is lignite; when somewhat disturbed and oblique the

coal is generally a gas or smokeless coking coal; when folded it becomes anthracite, and finally, when pierced by igneous rock, we have graphite.

COKABILITY.

In commercial work for our purposes coking coals have also to be classified as to cokability. In the following manner, which really is based upon oxygen content, though not requiring the tedious ultimate analysis necessary to give oxygen content, we have classified coals as to cokability, using as a basis the calorific value of the volatile matter contained. This, for coals of the same percentage volatile content, fairly represents cokability in actual coke oven practice.

CHART VII.

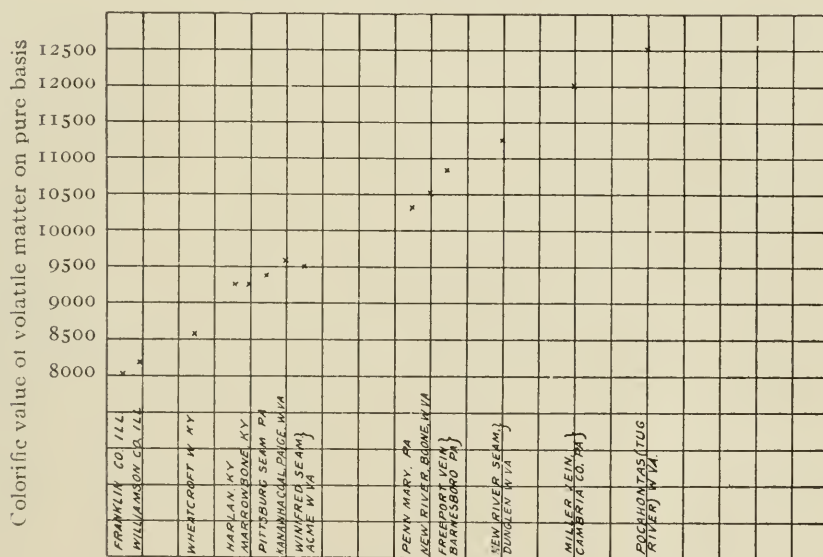


Table showing calorific value of volatile matter for typical coals of the United States.

On the previous chart (VI) the range of possible coking coals was indicated. Now, by deducting the calorific value due to fixed carbon (calculated) from the total calorific value, and dividing by the amount of volatile matter, all on the pure basis, we get a series of coals of increasing cementing or coking tendencies.

As shown on Chart VII, this variation in calorific value of the volatile matter has been found to represent results in actual coking practice.

As the calorific value of the volatile matter increases the cokability increases up to the point where the actual amount of volatile matter becomes insufficient to cement and hold the mass together. For example, semi-anthracite coals and anthracite, as to cokability, are beyond the limiting factor of insufficient cementing volatile material.

Cannel coal is unusual in that the calorific value of its volatile matter is higher than for any other coal with volatile so high. By the Ralston method of classifying and plotting it falls well above the usual curve.

Coals also differ as to the amount of materials contained capable of solution in caustic, pyridine, benzene and other solvents, and may be classified accordingly. So the residues from artificial carbonization at low temperatures give different amounts of matter soluble in the various solvents.

Finally, on exposure to moist atmosphere, coals decay. They become oxidized and go back in the series. For example, by taking up oxygen and water a good coking coal takes on the character of a poor sub-bituminous coal or the non-coking lignite.

Coals, and their by-products, are therefore not such mysterious materials. They are merely intermediate bodies resulting from the decomposition of ancient vegetation, just as a multitude of substances may be obtained by violent or gradual decomposition with heat of any simple organic compound.

COMMERCIAL MANUFACTURE OF COKE AND BY-PRODUCTS.

The conversion of bituminous coking coal to its anthracite-graphite equivalent, coke, has become of extreme commercial importance, and particularly when this is done with the recovery of the by-products. A ton of average coking coal will produce in the modern by-product oven:

1500 pounds coke.

18 to 26 pounds sulphate of ammonia.

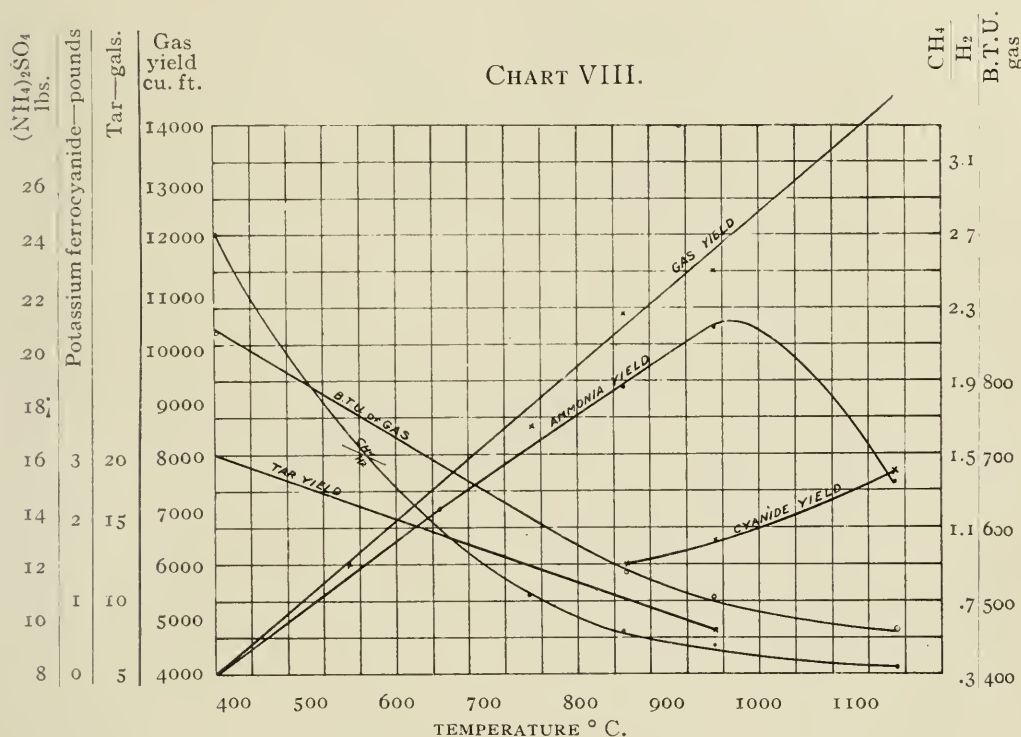
6 to 10 gallons tar.

1½ to 2½ gallons mixed light oils (benzole, toluole, xylene).

1½ pounds ferrocyanid.

By further elaboration, from these light oils and tar practically all the compounds mentioned in Beilstein may be produced.

On Chart VIII is indicated the influence of temperature upon the yields and character of the by-products obtained from an average coking coal. The temperatures given represent the hot-



test part of the retort at the beginning and end of the carbonizing period. The average temperature would be considerably lower.

On this chart the yield of light oil is not given, but our experiments indicate a maximum yield of this material at about 500° to 550° C.

VIRGIN COAL FIELDS IN THE UNITED STATES.

With this article are given some pictures selected from photographs taken by the writer to illustrate conditions in the virgin coal fields of the United States. These good Americans, with conditions of living which the discoveries of Koch and Pasteur have not yet reached, represent a backward glimpse into the frontier life of our own colonists' forefathers; this log cabin, timber clearing, horseback, spinning-wheel life with its quaint Shakespearean dialect is rapidly passing. A permanent record of some of these things is not, therefore, without scientific value.

Precipitation of Gold and Silver in Cyanide Solutions by Carbon. R. K. COWLES. (*Trans. Australasian Inst. Min. Eng.*, xvi, 58.)—In treating tailings, which also contained half-burned coal, etc., from power plants, by fine grinding in a weak cyanide solution for the recovery of gold and silver, it was found that the coal caused first the selective precipitation of the gold and later of the silver. Experiments showed that ground clinker, half-burned coal, and charcoal were all effective, but that unconsumed coal-dust had no action. The action appeared more rapid with fresh carbon than with carbon that had been saturated with water. The trouble was overcome by passing the tailings over vanners to remove the carbon.

Damascene Steel. W. GUERTLER. (*Int. Zeits. Metallog.*, v, 129.)—Damascene steel contains 1.0 to 1.6 per cent. carbon, and consists structurally of extremely small grains of cementite in a ground mass of ferrite. The characteristic appearance and properties of the steel are due to alternations of cementite-poor and cementite-rich zones. Prolonged heating at high temperatures, as recommended in the earlier literature, cannot possibly give the desired result. The most promising method seems to be to heat suitable steel, in which an extremely fine-grained structure has been induced, to a temperature below 700° C. for a sufficiently long period. The necessary preliminary structure may be produced by very rapid cooling, or by severe working above the eutectoid temperature.

Iron Ore Output of the World. C. K. LEITH. (*Times, Eng. Suppl.*, Feb. 4, 1913.)—The annual output of iron ore in the chief producing countries during the latest period (average of 1909, 1910, and 1911) for which the figures are available, was: United States, 50 million tons; Germany, 27; United Kingdom, 15; France, 14; Spain, 8; and Sweden, 5 million tons. Continued heavy production may be expected of the Lake Superior ores, the ores of the Franco-German boundary, the Bilbao ores of Spain, the Cleveland ores of England, and the high-grade magnetites of North Sweden; while increasing quantities of ores may be expected from Sweden and Cuba, and the use of Clinton hæmatites and Adirondack magnetites in the United States will also probably increase. In the near future there will probably become available the Brazilian high-grade hæmatites, Chilean ores, and ore deposits of the western United States, western Canada, India and China.

Non-Freezing Solutions. ANON. (*Amer. Mach.*, xl, 5, 186.)—"Compressed Air" points out that a mixture of 20 per cent. alcohol and water will not freeze above 10° F., 30 per cent. above 0° F., 35 per cent. above 10° below zero F., 40 per cent. above 20° below zero, and 50 per cent. above 35° below zero. The best alcohol is denatured grain (ethyl) alcohol.

CHANGES OCCURRING IN OILS AND PASTE PAINTS, DUE TO AUTOHYDROLYSIS OF THE GLYCERIDES.

BY

HENRY A. GARDNER,

Assistant Director, The Institute of Industrial Research, Washington, D. C.

IN seeds of the oil-producing type, enzymes are known to exist, which have fat-splitting properties and which exert a marked influence upon the metabolism of the growing plant. That these enzymes may continue their action, even when the oil from the seed is used for some commercial purpose, has probably never occurred to the student of paint technology. In previous investigations,¹ the writer has referred to the possibility of oil hydrolysis by enzymes, and has described the hardening action of free fatty acids upon various pigments. As a result of more recent work, the writer is convinced that many of the phenomena referred to are due to the action of enzymes. The data presented below include suggestive measures for preventing such action.

A majority of paints are made of linseed oil (pressed from flaxseed) as the chief constituent of the vehicle or liquid portion. Plant pathologists have recently shown that flaxseed is sometimes infected by a certain type of wilt or micro-organism which presents the proper development of the plant resulting from the growth of the seed. The yield and character of flaxseed produced by such plants are low and unsatisfactory. It is probable that crushers have at times received shipments of such seed, especially during years when small crops were obtained. When such seed is crushed for its oil content, part of the micro-organisms in the seed passes into the oil. The sediment or "foots" present in all raw oil is made up largely of mucilaginous and nitrogenous matter which affords an ideal sprouting medium for micro-organisms. The small percentage of moisture present in raw oil is also favorable to their growth.

¹ Notes on the Formation and Inhibition of Mildew in Paints. Journal Franklin Institute, January, 1913.

The Effect of Pigments upon the Constants of Linseed Oil. Journal Franklin Institute, October, 1912.

The Effect of Pigments Ground in Linseed Oil. Journal Ind. and Engrg. Chem., September, 1911.

Flaxseed is usually steamed, previous to expression, in order to break up the oil cells and render the expression more complete. This steaming process is usually conducted at relatively low temperatures which do not destroy the micro-organisms present. Spores may therefore be left in the seed, which may later develop micro-organisms identical with those present before the steaming process. These micro-organisms require food for their continued growth. In order to obtain such food, they evolve certain enzymes which have fat-splitting properties. It is the writer's belief that, under favorable conditions, the enzymes evolved by the micro-organisms present in crushed linseed oil energetically attack the oil and split it up into its component parts—free fatty acid and glycerin. Both of these substances are foods for certain types of micro-organisms. A freshly crushed linseed oil, of normal acid value of approximately 4, may contain enzymes capable of splitting up the oil and thus greatly increasing the acid value within a short time. If such oil is used in a paint containing basic pigments, trouble may ensue. After the oil has been split up, the fatty acid formed will react with the basic pigments and form metallic soaps which are not only insoluble in paint but which become annoying on account of their peculiar character. If the reaction has been strong and extended over a long period of time, difficulty may be found in brushing out such paint to a perfectly smooth surface.

The writer has recently examined a paste lead paint which was very granular in condition, and, as a result of the examination, is inclined to the opinion that the oil used in the paint was expressed from infected seed. This oil probably contained enzymes which split up the oil into its two component parts. The basic pigments in the paint neutralized a portion of the fatty acids which were set free, and thereby formed little lumps of insoluble fatty acid soaps which were apparently made up of the higher fatty acids. Another paste paint was examined and found to be very lumpy. The lumps could not be brushed out to a smooth surface. Some had the appearance of dried bits of paint skins. Others resembled lumps of wax. These lumps, upon analysis, were separated into a liquid fatty acid having an acid value of approximately 180, a solid fatty product having an acid value of 84, and a metallic pigment which was present in combination with a part of the organic acid as a metallic soap. The micro-organ-

isms in the oil paint may have had a selective action upon the lower fatty acids, thus leaving a concentration of the higher and more active fatty acids to combine with the basic pigment in the paint.

Previous to this investigation, the writer had obtained a sample of linseed oil which had been giving much trouble to pigment grinders. When this oil was used in making white lead paints, considerable thickening occurred after six months or a year. The oil was very cloudy in appearance. The following analytical results were shown:

Specific gravity .....	.9450
Iodine number	171.3
Saponification number	133.2
Acid number	4.1
Foots (per cent.).....	9.0
Moisture and volatile matter (per cent.).....	.68

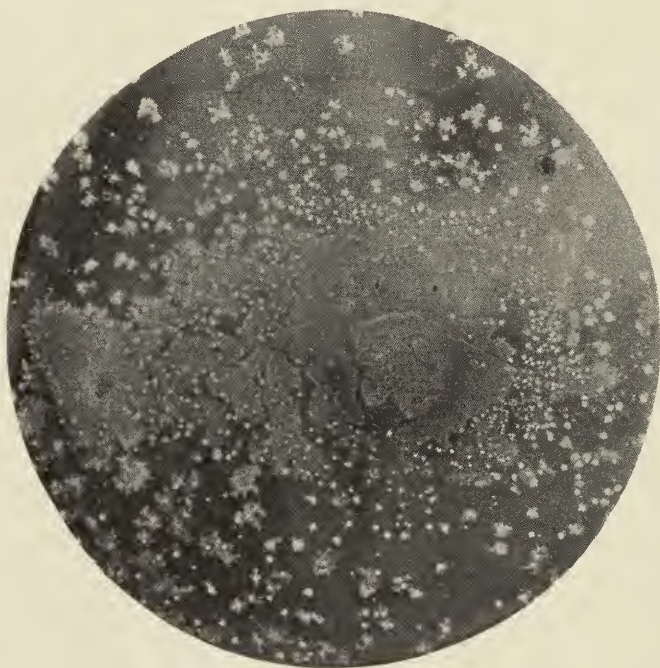
The large percentage of " foots " present had an acid value of 6.9. After clarification of the oil by repeated centrifuging, analysis gave the following normal constants:

Iodine number	177.3
Saponification number	190.2
Acid number	3.9

A sterile platinum needle was dipped into the " foots " obtained from the above described oil, and an extremely minute quantity was placed upon sterile agar-agar, gelatin and beef bouillon contained in test tubes. The tubes were placed in an oven at 37° C. At the end of 24 hours there was shown in each test tube a most marked development of white mould. Some of the incubated bouillon culture was then plated out upon agar-agar in petri dishes and again incubated at 37° for 24 hours. At the end of that time the surface of the agar was covered with micro-organisms which were growing in profuse quantities (Fig. 1). Some of these were transferred to a microscopic slide, stained, and examined with an oil immersion lens. A distinct form of bacilli was plainly shown (Figs. 2 and 3). In appearance, the bacilli were similar to the hay bacillus which is known to exist in some kinds of grain.

A portion of the above described oil was then mixed with corroded white lead and thoroughly ground to a smooth, heavy paste. The paste paint was placed in an oven heated to 37°C . and allowed to remain there for one week. At the end of that time an examination of the paint showed a few tiny granules, indicating that some reaction had taken place. A portion of the oil was extracted and its acid value found to be two points higher than that shown by the original oil, thus indicating hydrolysis. The presence of mere traces of acetic acid, free carbonic acid and

FIG. I



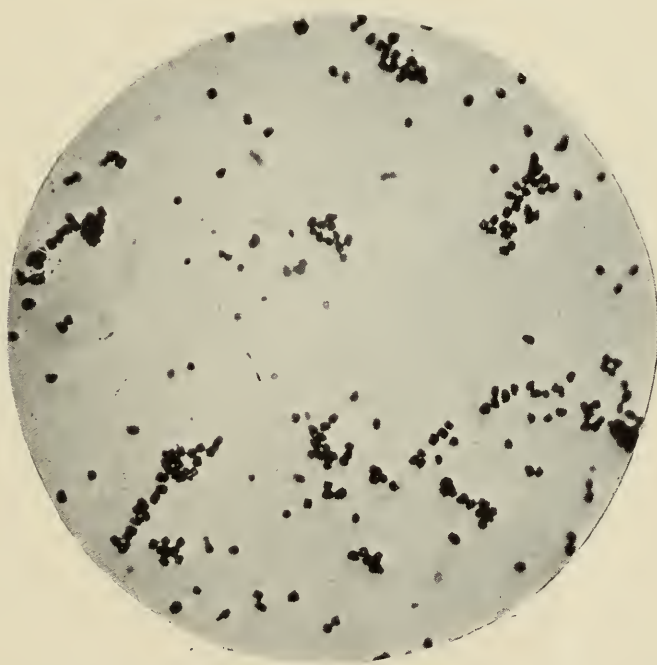
Colony of bacilli obtained from oil "foots" growing on agar agar.

moisture in white lead may have had an accelerating influence on the action of the enzymes. Such impurities probably act in a catalytic manner. Under favorable conditions, and with several weeks' time for reaction, much greater hydrolysis would have taken place. Within a year or two the lead paste might have become very granular. An experiment was then conducted to determine the effect of the micro-organisms present in the cloudy oil, when allowed to react with oils known to be free from such micro-organisms. A portion of the cloudy oil, which had shown a marked development of mould, was mixed with a sample of pure

linseed oil of known acid value. A few drops of water containing carbon dioxide gas were added. The acid value of the mixture was determined. At the end of forty-eight hours the acid value of the oil mixture was 10 per cent. greater than before.

Some experiments were then made to determine whether the bacilli in the cloudy sample of linseed oil could be destroyed by adding small quantities of antiseptic substances. The oil was distributed in test tubes and treated with small percentages of antiseptics such as cresol, carbolic acid, salicylic acid, sodium

FIG. 2.



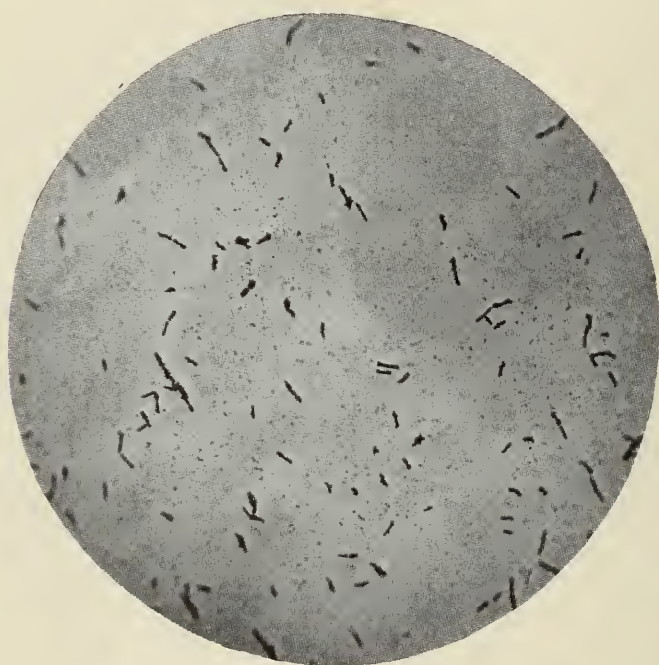
Mould spores obtained from "foots" of infected oils. $\times 1200$.
Oil immersion lens. Green light filter.

benzoate, etc. Sterile agar was then inoculated with these samples of oil, and incubated. At the end of twenty-four hours a development of mould was shown upon each, thus showing that the above named powerful antiseptic substances had not destroyed to any marked extent the micro-organisms present in the oil.

An attempt was then made to determine whether the micro-organisms could be destroyed by heat. Samples of the cloudy oil were heated individually to 100° , 150° , and 200° C. As soon as the maximum temperature was reached, the oil was im-

mediately allowed to cool. By this process the constants of the oil were not changed to any material extent. Test tubes containing agar were then treated with these heated oils. At the end of periods of twenty-four hours, forty-eight hours, seventy-two hours, and one week, absolutely no development of mould was shown. Bacilli could not be found in the incubated agar. These experiments indicate that the presence of micro-organisms in linseed oil, which comes from poor seed, may be destroyed by rapidly heating the oil to 100°C ., immediately withdrawing the

FIG. 3.



Bacilli obtained from "foots" of infected oil. $\times 1200$.
Oil immersion lens. Green light filter.

heat to prevent oxidation, and allowing to cool. This heating process has the added advantage of rendering the oil clearer and better suited for general purposes. During the past, some manufacturers have used refined oil which has probably been heated during the process of refinement to the critical temperature noted above. For this reason, paints made of such oil have not deteriorated. On the other hand, some manufacturers have used raw oil which has not been refined or heated to 100°C ., and such oil in some instances has probably been responsible for the granular condition observed in the lead paste.

It is interesting in this connection to record the condition of several prepared paints which were recently examined by the writer. These paints had been found among an old stock of supplies. They were packed in 1898. After sixteen years, no lumping, hardening or granulation had taken place. They were in perfect condition. Both lead and zinc whites were used in the pigment portion. The result of this examination would indicate that properly prepared paints made of good oil are capable of remaining in good condition for many years in sealed packages.

Since making the above outlined experiments, the writer has made a search of the literature bearing on the metamorphosis of oils, and has found several instances of the development of fatty acids in abnormal amount. Crampton² examined butter that had been kept in his laboratory for three years. The acid value had risen in that time from 5 to 109. He attributes this change to the action of moulds which were identified as *Coniosporium* and *Penicillium* (?). Similar experiments on butter were conducted by Koenig, Spiechermann and Bremer,³ who attribute the action to enzymes evolved. Lewkowitsch⁴ refers at length to the fat-splitting properties of enzymes, and points out the better keeping properties of lard rendered by steam at 100° to 120° C. as compared with neutral lard rendered at a low temperature not sufficient to destroy all of the enzymes present. Lewkowitsch also refers to the rancidity developed in a sample of palm oil, which had been kept away from light and air, as proving that enzyme action can take place in oils stored in closed containers.

It has occurred to the present writer that the rancidity of many oils could be prevented by inhibiting enzyme action. For instance, it is quite possible that the odor of fish oils is due to the development of evil-smelling free acids developed by enzyme action. If fish oils were treated immediately after pressing, it is possible that better smelling products could be secured from marine animals. That the study of enzyme action should extend to other oils used in the manufacture of paint and varnish seems to the writer as most important. Many of the peculiarities of such oils as tung and lumbang might receive more satisfactory expla-

² Journal Amer. Chem. Soc., 1902, 24-711.

³ Zeitschrift Unt. Nahr. und Genussmittel, 1900, 3-606.

⁴ Chemical Technology and Analysis of Oils, Fats and Waxes. Lewkowitsch. Vol. I, 37-38.

nation as a result of such studies. It is also possible that new light might be thrown upon the interesting subject of oil synthesis.

In summing up the results of the present work, the writer would call the attention of the oil crusher to the advisability of heating raw linseed oil to at least 100° C. previous to shipment. Oil which has been treated in such fashion is "immune," or "sterile," and will therefore be found much more satisfactory for grinding basic pigments having a lead or zinc base. The writer would also call attention to the necessity of using well-filtered oils. Oils having a large percentage of "foots" are always dangerous to use with basic pigments.

The writer desires to acknowledge the valuable assistance of Thomas M. Rector and W. G. Abbott in the microscopic and photographic work.

Non-corrosive Lead. ANON. (*Brass World*, x, No. 2, 63.)—Lead containing a small percentage of antimony or tin is much more non-corrosive than the pure metal. Lead pipe made from scrap resists corrosion better than pure lead. Specifications for lead cable frequently require that the lead coating of the insulated wire shall contain three per cent. of tin.

The Influence of Manganese on the Mechanical Properties of Gray Cast-iron. F. WÜST and H. MEISSNER. (*Ferrum*, xi, 97.)—Four series, each series containing 10 samples, were prepared with manganese varying from 0.2 to 2 per cent. in each series; total carbon about 2.79 per cent. in the first series, 3.08 in the second, 3.32 in the third, and 3.89 per cent. in the fourth; silicon about 1.5 per cent. in the first three series, and 1.7 per cent. in the fourth. Mechanical and microscopic tests were made on all the samples. The members of the fourth series, with the highest carbon content, gave markedly the lowest "strength" results. Of the other three series, the second, in which the combined carbon most nearly approached 0.9 per cent., gave the best results. In the fourth series the strength increased with the increase of manganese due to the graphite lamellæ becoming smaller. In the first three series, tensile and transverse strength attained a maximum with about one per cent. manganese. Flexibility and impact strength fell with increasing manganese, the effect being greater the lower the carbon content. Hardness rose with increasing manganese, but for the low manganese values it remained practically constant in consequence of the increasing separation of graphite. The formation of graphite increased as the manganese content rose to 0.3 per cent., but the higher amounts up to 2.5 per cent. had no further effect.

LIGHT SIGNALS.*

A DISCUSSION OF THE OPTICS, SOURCES OF ILLUMINATION, AND MOST EFFICIENT DISTRIBUTION OF LIGHT FOR RAILWAY SIGNALS GIVING DAY AND NIGHT INDICATIONS.

BY

C. O. HARRINGTON, JR.,

Union Switch and Signal Company, Swissvale, Pa.

CHAPTER IV.

LENSES AND REFLECTORS, INCLUDING A DISCUSSION OF PHANTOM INDICATIONS.

THE corrugated lens is generally used for signal lights on account of its cheapness, small weight, and more uniform cross-section. Where colored glass is used a fairly uniform cross-section is desirable, as otherwise the centre of the lens would be decidedly darker than the periphery. The corrugated lens is better adapted to pressing, and, as the expense of grinding is prohibitive in the case of signal lenses, the accuracy with which the corrugated lens can be pressed or moulded is a point in its favor. In Fig. 30, *A* represents a typical corrugated signal lens, and *B* represents a solid double convex lens having the same diameter and focal length; note the lighter construction and more uniform cross-section of *A*. For a more detailed discussion of the signal lens the reader is referred to a paper entitled "The Optics of the Signal Lens," by Dr. William Churchill (*Railway Signal Association, Annual Proceedings*, 1906).

Assuming a source *O*, Fig. 31, projecting light equally in all directions: the fraction of the total spherical candle-power pro-

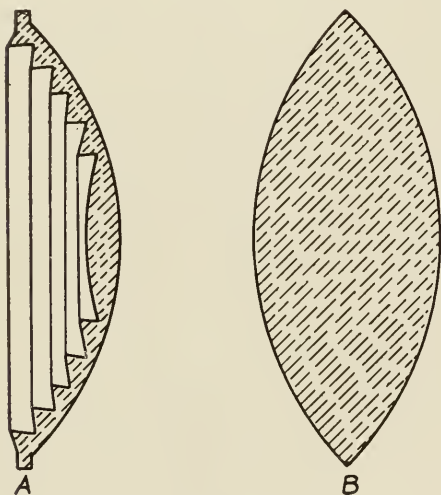
jected by the lens is $\frac{1 - \cos B}{2}$, and therefore increases with the angle *B* which the lens subtends. *B* is known as the "aperture" of the lens, and is limited by the total reflection of ray *OX* in the direction *XS* when the deflected light *AX* strikes the convex face of the lens at the critical angle.

For the ordinary "smooth-face" lens common practice has fixed 80° as the greatest value of *B*, chiefly with the purpose of

* Continued from page 408.

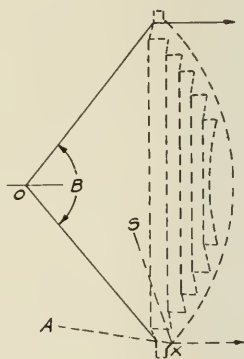
avoiding wasteful dispersion of light on the lens steps. By employing suitable lenses or combinations of two or more lenses, it has been found possible to increase the aperture considerably, and by increasing the value of B to secure greater "geometrical efficiency." We shall use the term "geometrical efficiency" to describe the percentage of total spherical candle-power impinging on a lens or reflector. We should conclude from this that the two lenses illustrated in Fig. 44 are more efficient than the ordinary signal lenses, as each have considerably larger aperture. However, the increase in "geometrical efficiency" does not add to the axial intensity of the projected light, its effect being to increase the spread. It does not neces-

FIG. 30.



A Fresnel lens and its equivalent.

FIG. 31.



sarily follow that the lens having the greatest aperture is best suited for signal purposes. Different lenses and reflectors cannot be compared directly on this basis, as much candle-power may be lost by reflection or refraction of light at large angles; nevertheless geometrical efficiency deserves careful consideration as it is an important factor in securing the maximum effective illumination.

The adoption of a single concentrated filament lamp at the focus makes the parabolic reflector a possible substitute for the lens. A formula for the geometrical efficiency of the parabolic reflector illustrated in Fig. 32 is submitted herewith, it having been developed by Messrs. M. D. Cooper, of the Engineering Depart-

ment, and C. E. Terry, of the Brilliant Electric Division of the National Lamp Works of the General Electric Company.

E equals geometrical efficiency (per cent.).

F equals focal length.

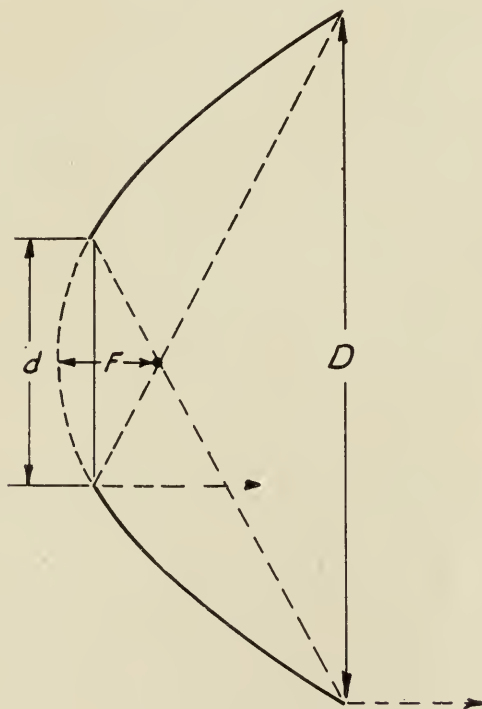
D equals diameter of front opening of reflector.

d equals diameter of opening in back of reflector.

$$E = 400F^2 \left[\frac{1}{4F^2 + \left(\frac{d}{2}\right)^2} - \frac{1}{4F^2 + \left(\frac{D}{2}\right)^2} \right].$$

Before discussing the merits of different forms of light projectors, it is necessary to consider the limitations incurred by

FIG. 32.



Parabolic reflector. Geometrical efficiency.

safe design. To secure the greatest efficiency a parabolic reflector or a lens combined with reflector should be used. Referring to Fig. 33, it will be evident that light can enter either of these light signals and be reflected back in such a manner as to present an apparently illuminated signal.

Phantom indications are both undesirable and unsafe, and careful consideration should be given to means for eliminating

them. Especially where electric head lights are used, or where signals are located so that sunlight may at some time during the day shine directly into the lenses, every precaution should be taken to eliminate all possibility of phantom indication. To avoid phantom signals with a lens, it is necessary to omit the reflector *A*, Fig. 33, or to relocate or use only part of said reflector. In addition to this, a careful study should be made of the effect of all glass parts in the vicinity of the focus as these may become sources of phantom indication.

To avoid phantom signals from reflectors it is necessary to employ special designs of reflectors combined with certain interference rings and shields designed to prevent external light entering the light signal from being reflected back in the observer's

FIG. 33.

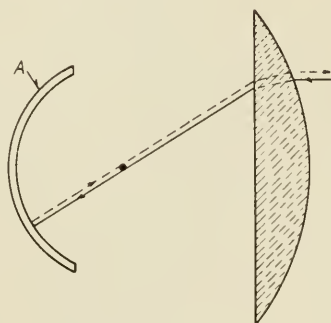
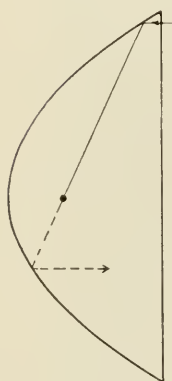
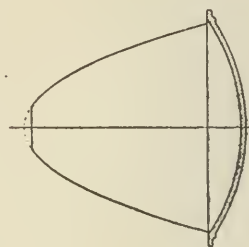


FIG. 34.



eyes. The complication in design incident to the avoidance of phantoms may thus develop into a serious argument against the use of reflectors in light signals.

The author does not believe it necessary to describe the numerous schemes which have been proposed and tried during recent light signal development, but it should be understood that very careful investigation has been made to determine the causes of phantom signals and the best means of avoiding them, with the result that it is now possible to design a signal on which numerous tests, both in sunlight and with powerful head lights at night, show that no perceptible phantom may be anticipated.

In this connection it is interesting to note that where glass "roundels" are used these should be made convex as shown in Fig. 34. Unless this is done the glare of light reflected from a plane glass roundel may be sufficient to blot out the signal indication.

Cases have also been observed of colored roundels where reflection from a rear face of a plane roundel was sufficient to give a distinct colored indication.

To analyze the different types of lenses and reflectors which have been considered in designing a light signal, or to attempt to compare their merits, would require more space than can be allowed at the present stage of the subject. For commercial reasons the author has found it best for the present to adopt the single concentrated filament lamp and with that lamp to develop the best optical combinations for immediate practical application.

FIG. 35.

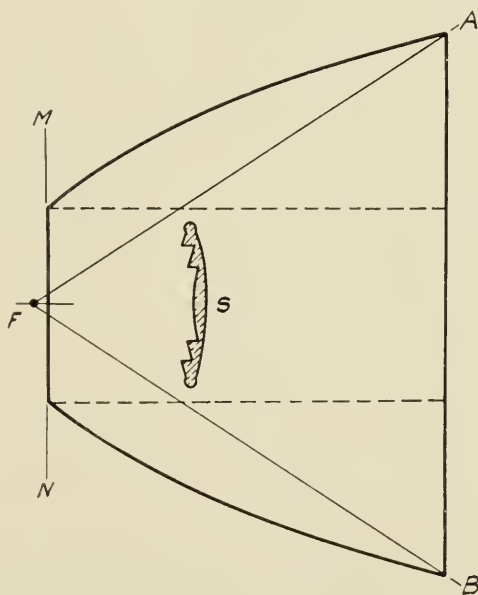
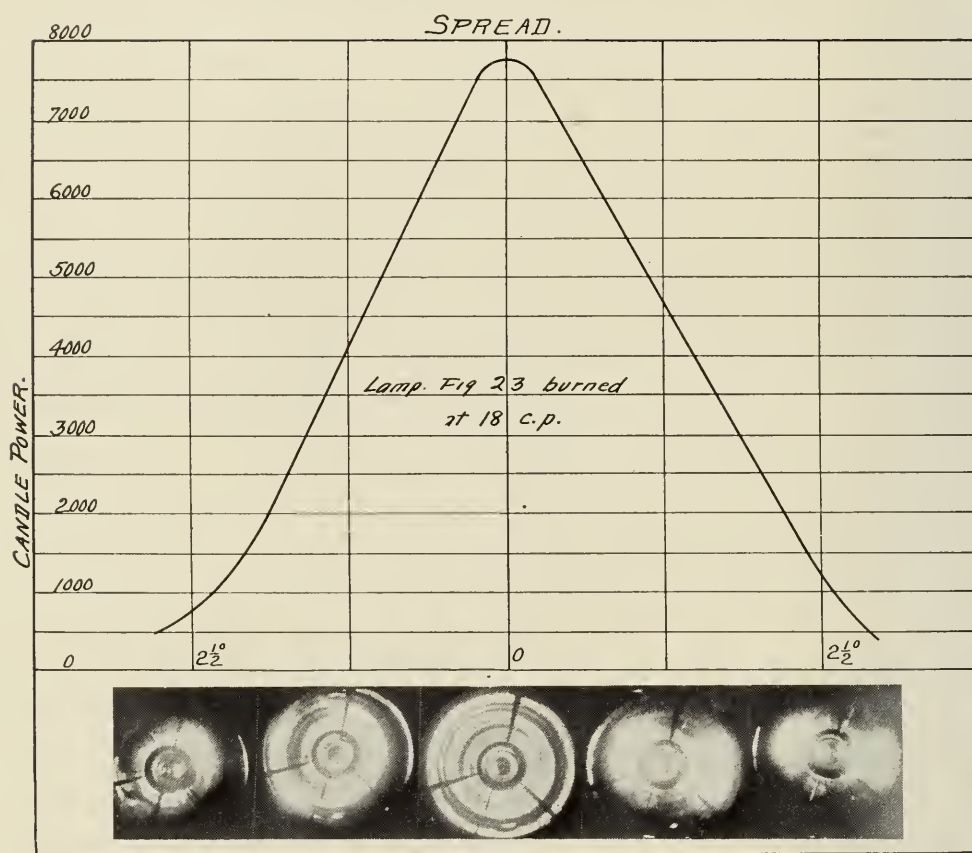


Fig. 36 shows photographs and candle-power distribution of light from the combination of reflector and lens shown in Fig. 35. This combination of reflector and lens is the result of extensive tests which it is unnecessary to describe here, but which determine the best size and focal length for both. There are many things which must be taken into account before it is possible to design an efficient reflector which will not present serious phantom indications where arc head lights are involved or where sunlight shines directly into the signals. The combination covered by Figs. 35 and 36 has geometrical efficiency of about 35 per cent. and represents the best results which it is possible to secure with absolute safety; it serves, therefore, as a fair basis for the comparison of the reflector with the lens.

The type of lens to be used depends entirely upon the spread and candle-power considered necessary and the type of lamp available. As already noted, a large spread and low candle-power can readily be obtained by using a large lamp filament; such distribution of light is well illustrated by the candle-power curve on Fig. 24, using the 25-watt, 110-volt standard Tungsten lamp. Where good color indications are required at distances of 2000 feet or

FIG. 36.



Combination of 3-inch lens and 10-inch metal parabolic reflector.

more in broad daylight, experience has shown that a high beam candle-power is necessary, and for such conditions we need, in addition to a concentrated source of light, a lens of high efficiency which will be capable of projecting a highly concentrated beam of light. The best type of lens cannot be determined without knowing the size and shape of the lamp filament.

The concentration of light at the focus of the lens obtained by using a compact incandescent filament similar to Fig. 23 is, of

course, of the greatest importance. We show, however, on Fig. 44, two candle-power curves which illustrate the influence of the lens itself in projecting light. These curves represent two typical lenses, each having the same lamp filament at the focus. The lenses shown in Fig. 44 are submitted only as an interesting comparison, and do not necessarily represent the best construction which is possible. In fact the development of high candle-power light signals is yet too much in its infancy to warrant any definite statement at this time as to the best type of lens to be used.

Our experience to date would indicate that the lens is more desirable than any construction of parabolic reflector so far developed. Moreover, the lens costs less than the parabolic reflector of anywhere near equal efficiency, and it seems evident that dust, frost or "sweating" will have less effect in impairing its efficiency. To offset the increased cost and the greater efficiency depreciation to be expected in service, it would be necessary that the parabolic reflector show decidedly higher candle-power than could be obtained with any lens.

CHAPTER V.

CANDLE-POWER: ITS RELATION TO RANGE OF LIGHT SIGNALS.

In developing a satisfactory signal we should aim to secure a minimum range of 1500 to 2000 feet under the most unfavorable weather conditions which can be encountered. Unfortunately, we are still confronted with the occasional necessity of locating signals on sharp curves or where obstructions exist which prevent a clear range of even 1500 feet; this problem can be solved only by care in locating signals or providing overlap protection for those signals which cannot be properly located, and this condition does not invalidate the arguments for long range which have been offered in the first part of this article. Light signals show up best where they have some background; in fact, those locations commonly considered undesirable will generally be found best for these signals. The light signal is least distinct when displayed on a sky background with the sun in the observer's face; obviously, therefore, tests for candle-power and range must be conducted under these unfavorable conditions.

In this connection it might be noted that where either candle-power or candle-foot illumination is mentioned the same is based

on uncolored light; the colored glass used for light signals will reduce the effective candle-power to between 10 per cent. and 20 per cent. of the uncolored light.

A large number of field tests have been made with signals of different candle-power, employing lenses or reflectors of different sizes and equipped with roundels of different colors and densities. These tests have afforded conclusive proof that the visibility of a signal may be measured by the candle-foot illumination which this signal projects upon the observer's station. Theoretically, the candle-foot illumination necessary for visibility should be uniform at all ranges. A little study of conditions will make it plain that, owing to the decreasing prominence of the background on the longer ranges, the light has less of the black backing so necessary to set it off properly. As the range increases the light itself presents a smaller object to the eye, which makes it increasingly difficult to distinguish color accurately.

To correct for the conditions just outlined, it is necessary to employ a background of liberal size (3 feet to 4 feet diameter has been favored) and to increase the diameter of the lens. Of two lenses projecting beams of the same intensity, the larger lens will be visible at the greatest range as it presents the larger object to the eye. It is also necessary to increase the candle-foot illumination with the range, in order to correct for the decreasing prominence of the signal, making the candle-foot illumination for a 2500 foot range several times greater than that necessary for a 1000 foot range. This will, to a great measure, compensate for the difficulty experienced in recognizing colors. It is also desirable to establish some minimum candle-power at ranges under 600 feet, and not attempt to apply the candle-foot rule, which would here result in ridiculously low candle-powers. Of course, the candle-foot illumination necessary for visibility will show astonishing variations with slight changes in the weather and in the location of the signal. However, by taking the precaution noted above and securing data under the most unfavorable conditions, a set of candle-foot values may be obtained which will eliminate an endless amount of work by providing an accurate formula for calculating the candle-power necessary for any type of signal, once the desired range is assumed. Thus, to determine the candle-power of a signal where range must be 1500 feet, make

$C.P. = i(1500)^2$ where i is the proper candle-foot value selected from the standard data.

In practice the author is convinced that it will not be difficult to find advantageous locations for light signals, especially in congested territory and where bridges on the right of way offer good background, and that where light signals must be located with sky backgrounds and the morning or evening sun behind the signal the disadvantage of location may be offset by applying larger backgrounds to the signals. In foggy weather the high candle-power light signal gives very satisfactory service, there being little trouble in getting distinct signal indications at 1000 or 1500 feet, as desired. It is in just such weather that we are apt to experience the greatest delay in moving traffic and at the same time incur the greatest risk of engineers overrunning signals in an attempt to make up time.

Reference to the exact candle-foot values necessary for visibility has been avoided, as these values are directly influenced by the density of the colors used, and color is a subject on which different railroads may not at once agree. For a further discussion of colors the reader is referred to Chapter VIII.

CHAPTER VI.

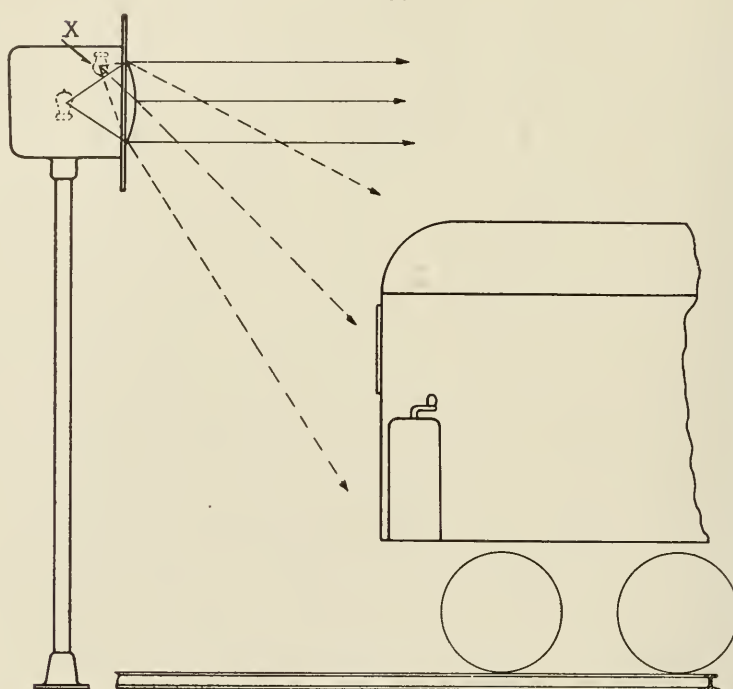
DISTRIBUTION OF LIGHT.

On straight track a signal need have only enough "spread" to permit convenient alignment. Experiments under practical operating conditions show that about 2° total spread will permit reasonably convenient alignment on tangent track. To make it possible to see the signal indication when standing close to the pole or bridge on which the signal is mounted, it is necessary to project a small percentage of the light downward. Engineers frequently have occasion to read the signal indication when standing very close to the signal (see Fig. 37), and it is important that this indication be perfectly definite, as if we permit any indistinct glitter to be taken as a signal indication we increase the danger of a phantom signal.

It is a practical certainty that with the precautions already cited no phantom will be observed which can be confused with the brilliant illumination of the light signal when viewed from straight ahead. Three devices have been used to provide

a definite indication to the engineer standing nearly below a signal; the most obvious is to use a signal light with a great spread, but this is decidedly uneconomical, as it involves a fla-

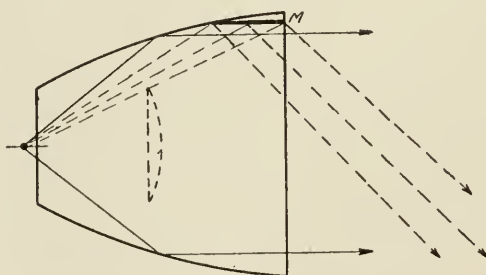
FIG. 37.



An auxiliary light for short ranges.

ment of large area, only a small portion of which is really useful for long-range indications. The second device comprises one lamp at the focus of lens, and a second lamp of less candle-power

FIG. 38.

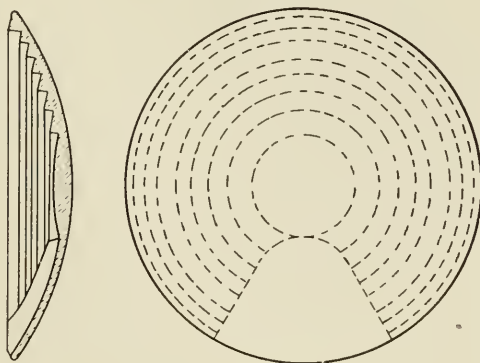


if desired, located at X, Fig. 37, so as to project light downward. The arrangement shown in Fig. 37 has given practical and satisfactory service for several years; the only objection which may be cited against it is that two lamps are necessary and that one

of these is inefficient and practically useless for long-range indication.

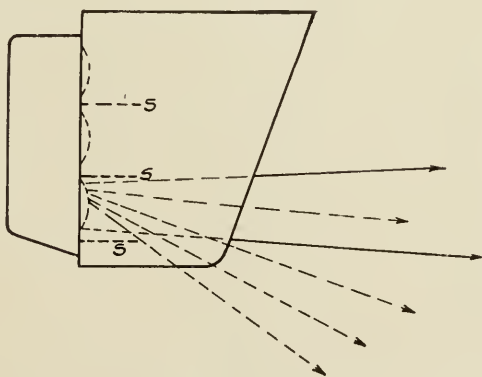
The "pilot light" *X*, Fig. 37, may in some situations be justified by its useful function as a marker. Where an independent marker *A*, Fig. 25, is employed, especially on single

FIG. 39.



track blocking, the failure of a signal light results in a stop signal and it may be necessary to flag a train through the block. By using the pilot light *X*, Fig. 37, as a marker, failure of the signal light results merely in a short range indication: the engine runner will be compelled to slow up but need not come to a stop, and can

FIG. 40.



Shields to prevent engine runner standing directly under signal.

enter the block with a perfectly clear signal indication. In this case the same arguments presented for Fig. 25 apply, a rugged lamp of long life being indispensable. Of course, the pilot lights *X* are controlled through the same relay contacts which control the signal lights; a defective relay contact may thus result in the

absence of any indication, an accident impossible with the marker light *A*, Fig. 25, which is burning continually and is not dependent on contacts of any description.

FIG. 41.

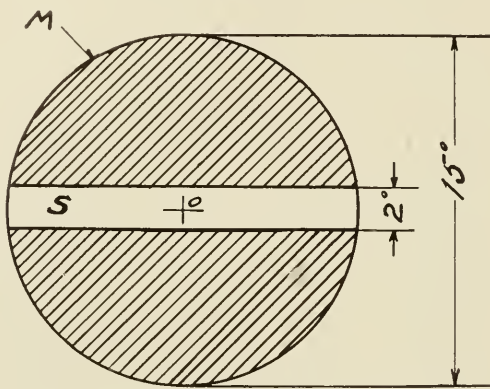
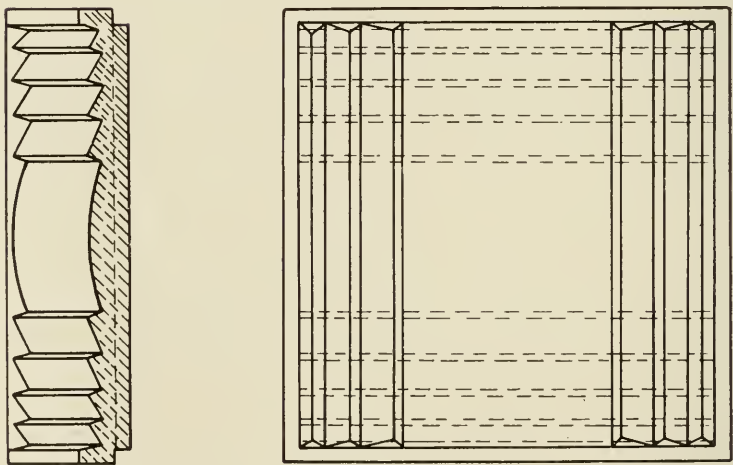


FIG. 42.

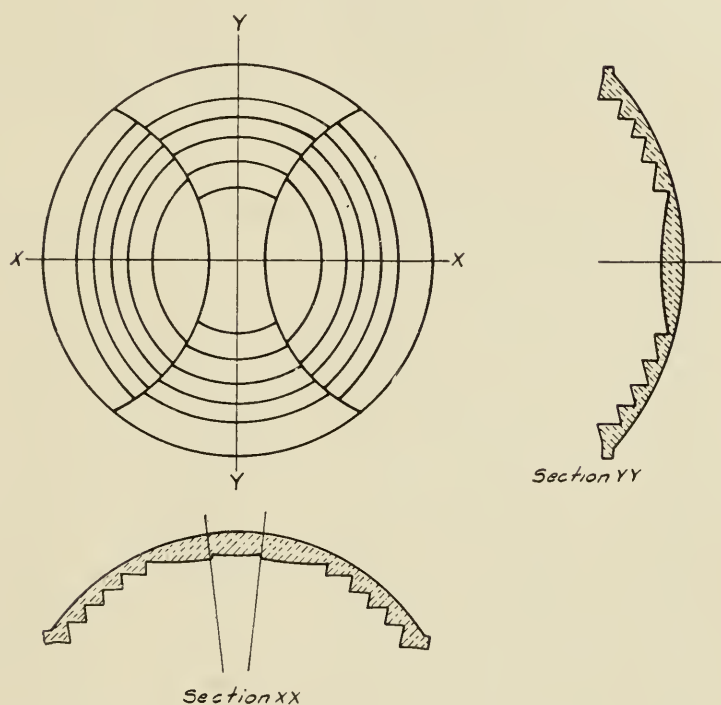


Lenses designed with more horizontal than vertical spread.

In the third scheme an independent repeater signal of low candle-power is connected in multiple with the green signal light and located as shown in Fig. 48, so as to be visible within that portion of the track near the signal not covered by the light signal

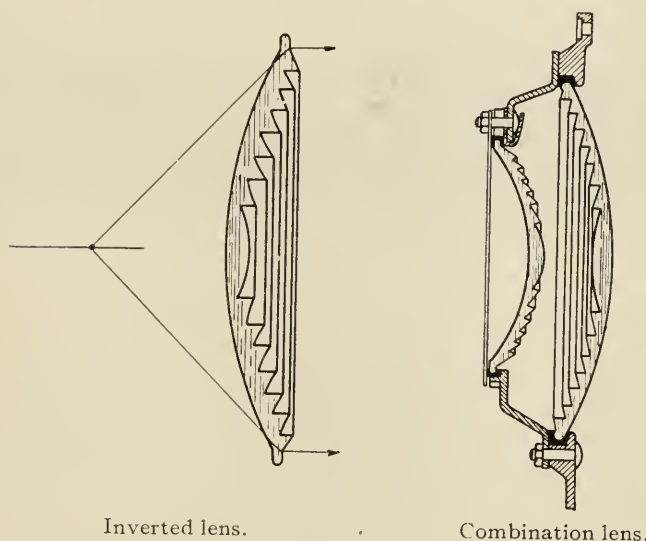
proper; however, this involves not only extra lamps but an extra signal and wiring as well.

FIG. 43.



Lenses designed with more horizontal than vertical spread.

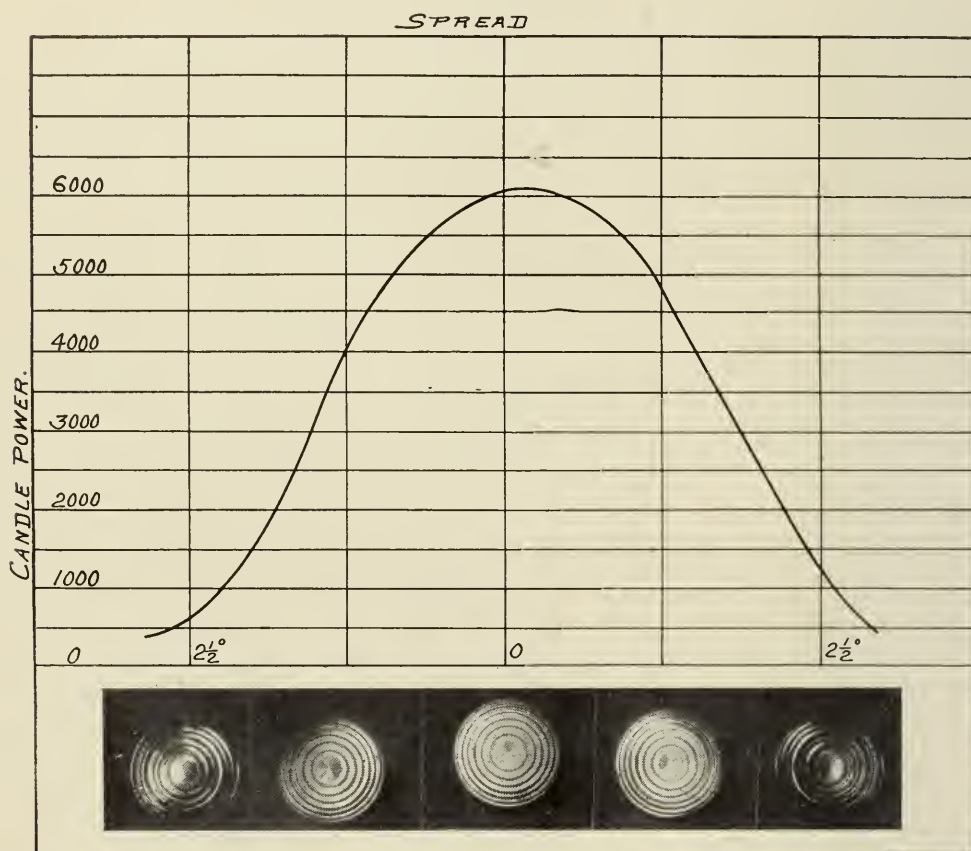
FIG. 44.



The author believes it better to use only one lamp in each signal, and either to locate reflectors *M*, Fig. 38, in some position to project a portion of the light down to that portion of the track

close to the signal, or else secure the same result with a lens shown in Fig. 39 having a small portion of its surface free from corrugations, so that the lamp can be clearly seen. It is not necessary that an engineer stop directly under a light signal; he can just as easily be required to stop 25 feet or 50 feet before he reaches the signal; to prevent the engineer from approaching so close that

FIG. 44A.



Combination lens. Lamp, Fig. 23, burned at 18 c.p.

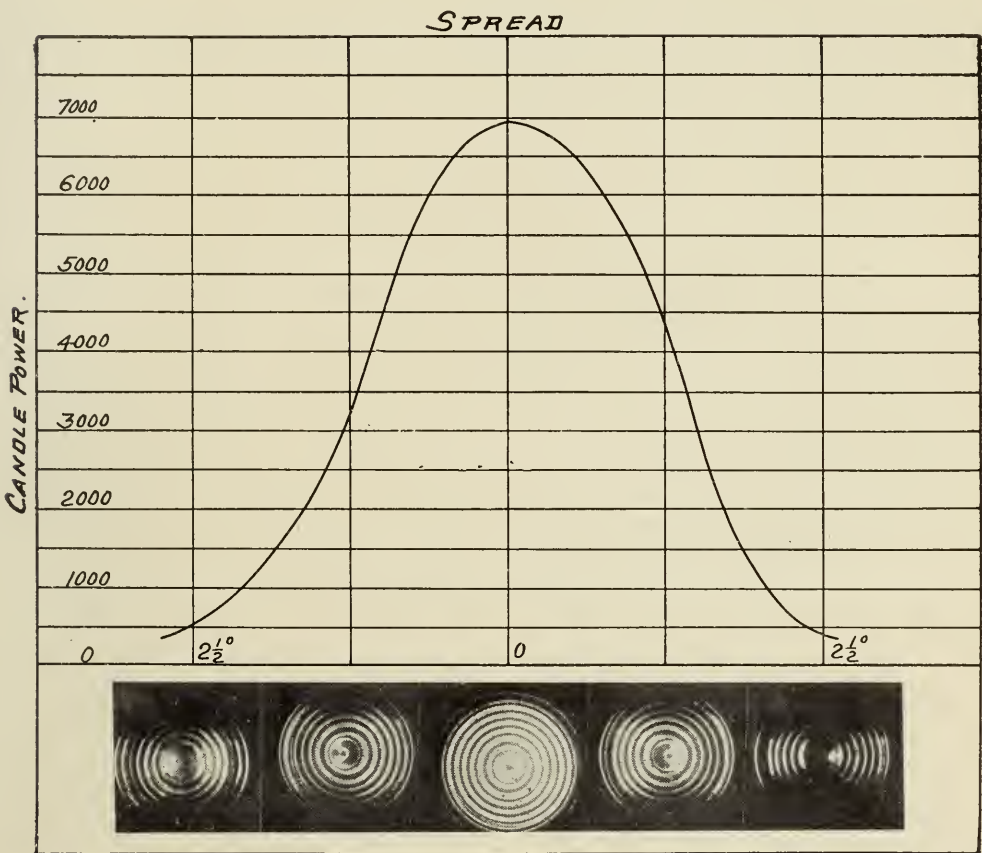
he cannot definitely recognize the signal indication it is best to equip each signal with shields *S*, Fig. 40, so designed that the engineer cannot see the signal indication if he approaches closer than 25 to 50 feet; with this arrangement you either get a distinct signal or none at all, and there is no opportunity for an engineer to stop in a position where he must either back up or take a guess at a doubtful indication.

Wherever possible, signals are located on tangents; very many signals must be located on curves, and we are, therefore,

confronted with the necessity of distributing light through a comparatively wide angle with as little waste of power as possible.

The light projected from a lens or reflector may be spread uniformly around the axis *O*, Fig. 41, which represents a beam of light projected on a screen, by increasing the area of the source of illumination or by placing this source out of focus; in Fig. 41,

FIG. 44B.

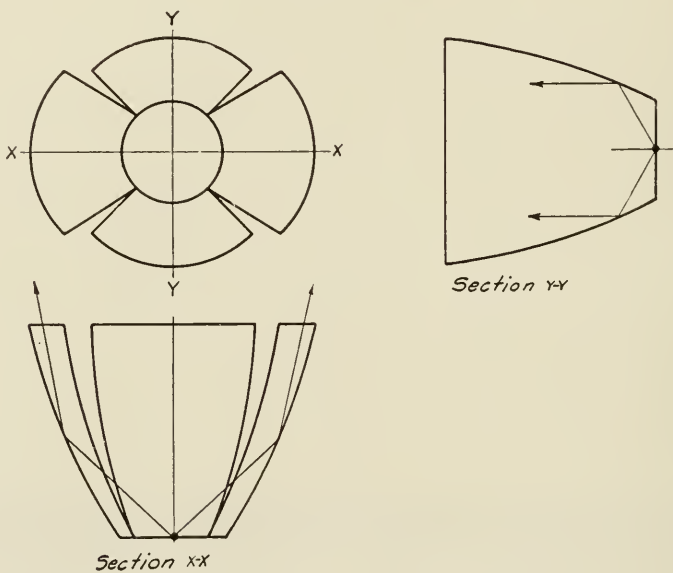


Inverted lens. Lamp, Fig. 23, burned at 18 c.p.

M represents the circle in which this light would be projected upon a screen. The spread in a horizontal plane must in many cases be 15° , often more; the vertical spread need only be enough to make alignment reasonably easy, say 2° , as the variations in grade of track will usually not require more than 1° vertical spread; hence the required distribution of light is indicated by *S*, Fig. 41, and the shaded area included between *M* and *S* represents wasted light.

The horizontal spread can be increased with relation to the vertical spread by placing a long incandescent filament at the focus, horizontal and at right angles to the axis; this involves some waste of power, as only a small percentage of the filament is at the focus, and the remainder, being out of focus, projects light inefficiently. Or the filament can be concentrated near the focus and the lens or reflector be designed to spread light horizontally; thus in Fig. 42 the lens is compounded of two sets of prisms at right angles to each other, so that the horizontal and vertical spread may be regulated independently. We can thus disperse light in a horizontal plane and avoid unnecessary spread

FIG. 45.



A parabolic reflector designed for increased horizontal spread.

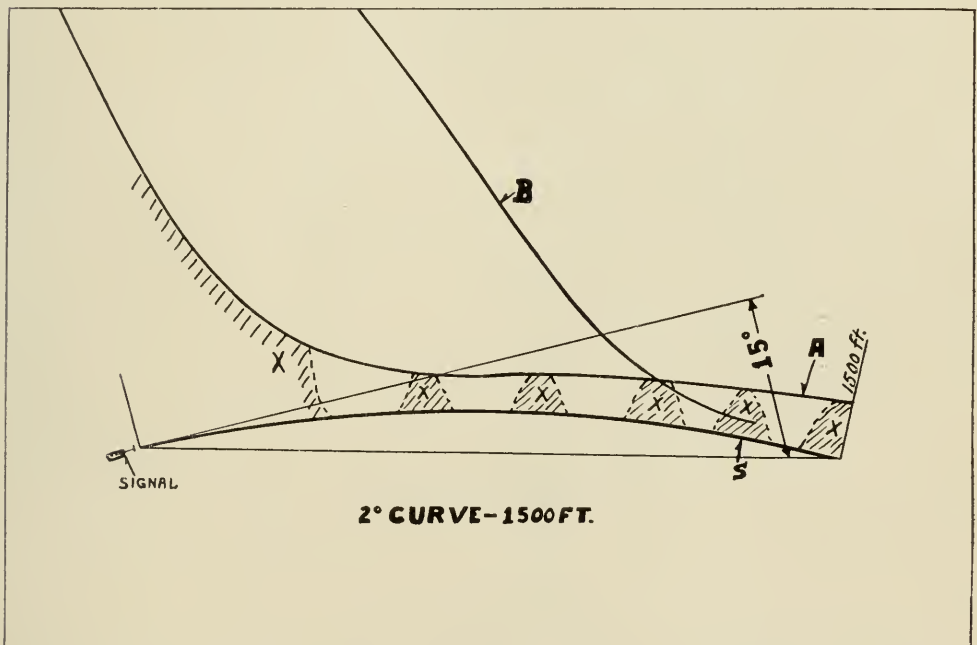
in the vertical plane; in Fig. 43 the lens is compounded of three sections, designed to project light on three different axes in a horizontal plane; Fig. 45 shows the same principle applied to a parabolic reflector, three segments of the reflector being aligned so as to project light along three different axes. In both Fig. 43 and Fig. 45 the light from the different sections is intended to overlap so that the signal may be seen through the entire angle.

Signalling on Curves.

Apparently no consideration has heretofore been given to designing a light signal to conform to the requirements of railroad curves. S, Fig. 46, is submitted as a typical curve; on this

curve as a base the line *A* is plotted, the distance between *S* and *A* at any point representing the candle-foot illumination required if the signal is to be clearly visible from that point. *A*, Fig. 47, is the candle-power curve corresponding to *A*, Fig. 46, and the reader will note that the symmetrical dispersion of candle-power provided by any of the lenses or reflectors previously mentioned is entirely unsuited to the purpose. As an example the author submits *B*, Fig. 47, the curve of a doublet lens with $\frac{1}{2}$ -inch 15 candle-power horizontal filament at right angles to the optical axis, and *B*, Fig. 46, illustrates the inefficient distribution of the

FIG. 46.



light from this lens along curve *S*, the illumination at the centre of curve being far higher than necessary, while the more distant portions of the curve do not get sufficient illumination. It is obvious that a signal designed to distribute light unsymmetrically per curve *A*, Fig. 47, will provide a greater spread, can be seen from a greater distance on curve, and yet can be operated with less lamp watts than any existing form of light signal.

To secure more uniform candle-foot illumination on a curve, we have worked along new lines and designed a combination of lens and parabolic reflector as shown in Fig. 49. The reflector is divided in two sections, having optical axes divergent: section *A*, projecting a major portion of the light, is to be lined up on the

FIG. 47.

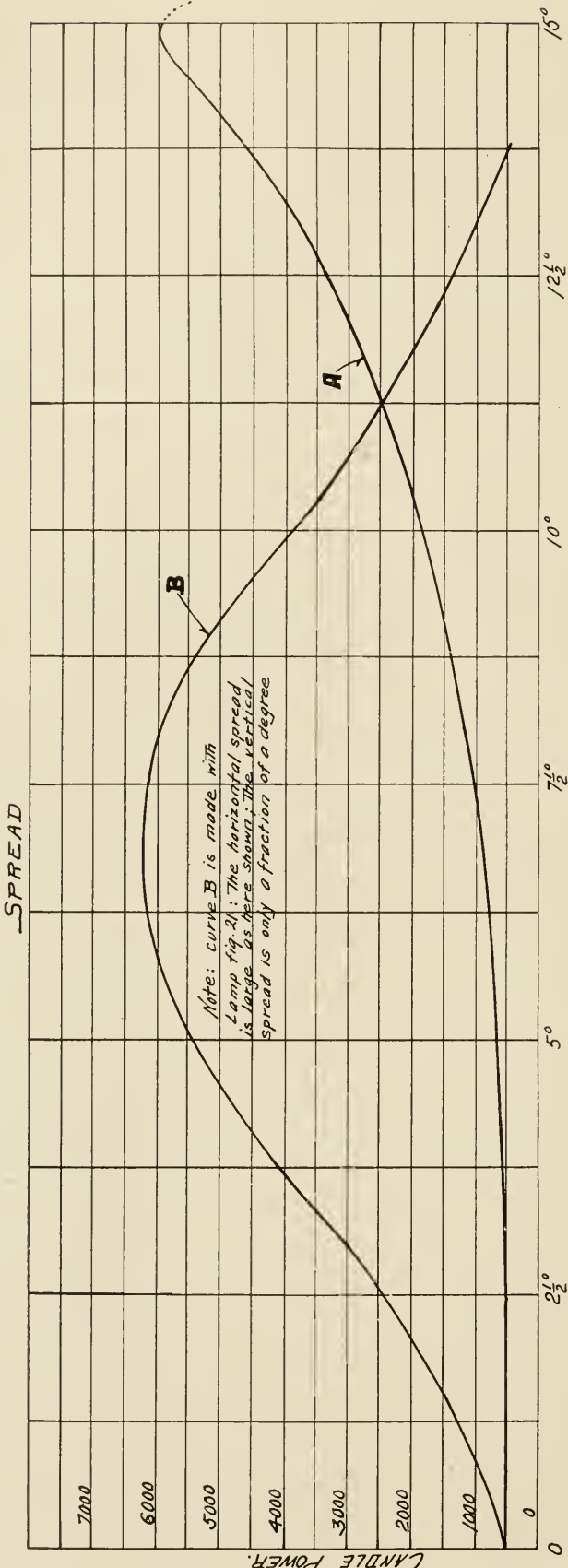
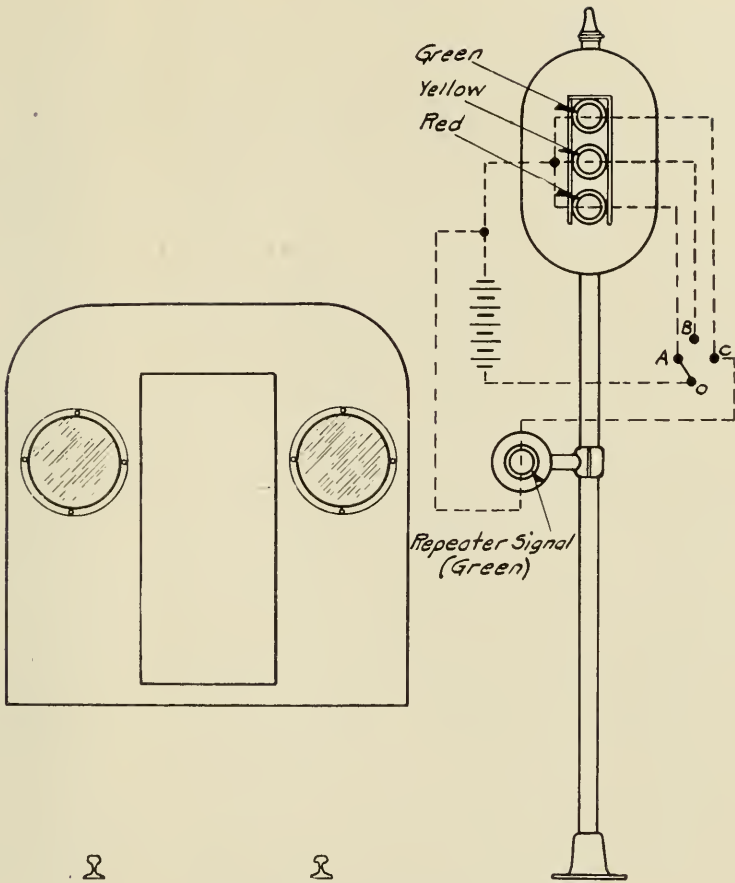
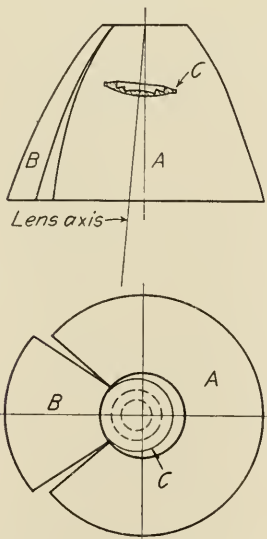


FIG. 48.



Repeater signal for short ranges.

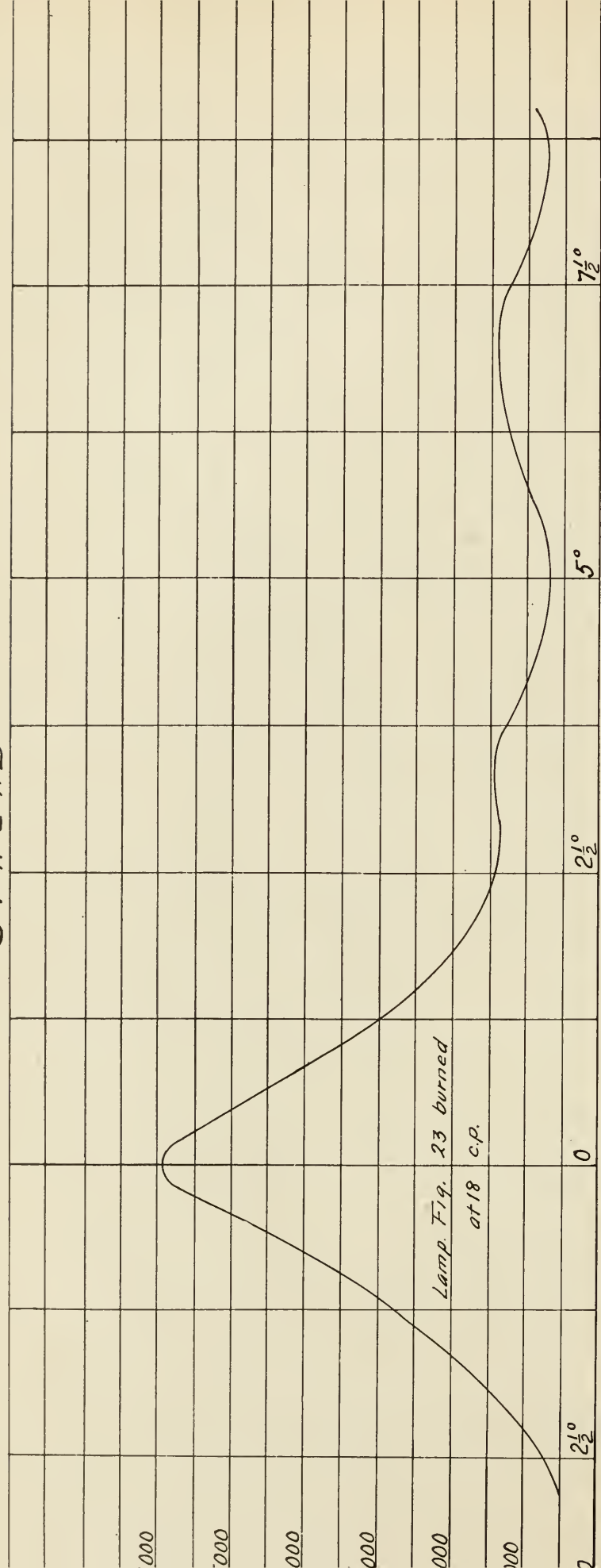
FIG. 49.



A combination of lens and reflector for signalling on curves.

FIG. 50.

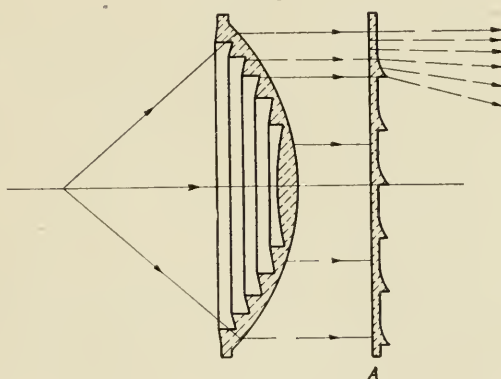
SPREAD



Combination of lens and parabolic reflector, Fig. 49, for curve alignment.

most distant portion of the curve, section *B* and lens *C* project other and smaller portions of the total candle-power over the remainder of the curve. The object is to secure more efficient distribution of light by projecting the higher candle-power on the remote ranges and lower candle-power on the nearer ranges.

FIG. 51.

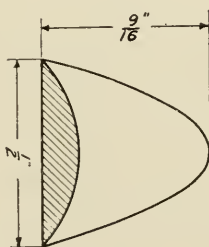


A refracting screen for signalling on curved track.

Fig. 50 includes photographs of the signal at different angles, and its candle-power distribution.

The signal shown in Figs. 49 and 50 does not meet requirements perfectly, as it concentrates light on three axes: to secure a perfect distribution of candle-power, as curve *A*, Fig. 47, it is best that some form of prismatic screen, as, for example, *A*, Fig.

FIG. 52.

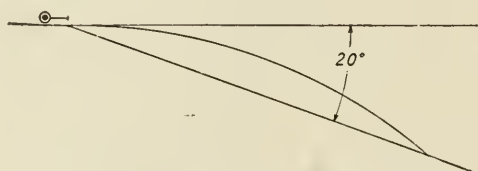


Standard flat flame long time burner for semaphore.

51, be placed in front of an ordinary lens or reflector, the prisms comprising this screen having such form that the light may be distributed as required. This prismatic screen has the advantage of being an adjunct of the regular light signal, and may be built with different prism angles to cover various degrees of curvature up to about 40° central angle. When signalling on

sharp curves, or under the necessity of increasing the brilliance of the light, the same general effect may be secured with the same lamp watts by concentrating the light flux at several points on the curves, the light distribution being as shown by *XX*, Fig. 46. For ordinary use on straight track the prismatic screen may be removed.

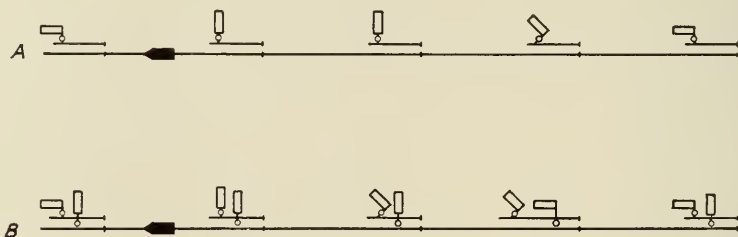
FIG. 53.



Spread of light from a semaphore lantern.

The standard semaphore signal is limited by the curves which can be included in the spread of the semaphore lantern. Most semaphore lanterns are equipped with five-day oil burners of the flat flame type, the flame of which is illustrated in Fig. 52; the use of the flat flame burner is nearly universal, and it appears to be giving good satisfaction. We have, therefore, measured the angle through which a standard semaphore lantern with clear

FIG. 54.



A. Overlap protection. B. Three block indication.

lens, red roundel, and flat flame (Fig. 52) can be seen on an average clear night, and find it will just satisfactorily include the curve, Fig. 53. In determining the angle (20°), the semaphore lantern was lined up so that in front of the signal one could see a fairly well-filled lens giving a distant indication. On the basis of these tests the author has concluded that a spread of 15° to 20° will meet average railroad conditions.

In certain exceptional cases where this is impossible either signals of great spread and correspondingly high wattage may be used, or the light be concentrated on several points on the curve,

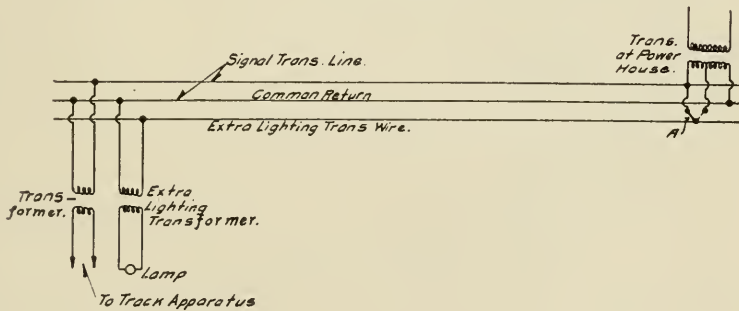
as shown by *XX*, Fig. 46, or, as the last resort, extra protection be afforded by providing overlap signals so that a train will either leave two danger and one caution signal behind it (*A*, Fig. 54), or one danger and two caution signals *B*.

CHAPTER VII.

REDUCTION IN CANDLE-POWER AT NIGHT.

When it is remembered that the present semaphore lantern with $\frac{1}{2}$ candle-power oil flame (Fig. 52) projects a beam of 60 candle-power and gives a sufficiently brilliant signal for night indication, it is obvious that the light signal may prove far too brilliant at night; in fact, it is as powerful as a small automobile headlight. For this reason it would seem advisable to reduce the lamp voltage at night and thus lower the candle-power to about 500, which tests have shown not to be high enough to cause any annoyance.

FIG. 55.



Circuits for controlling voltage at night.

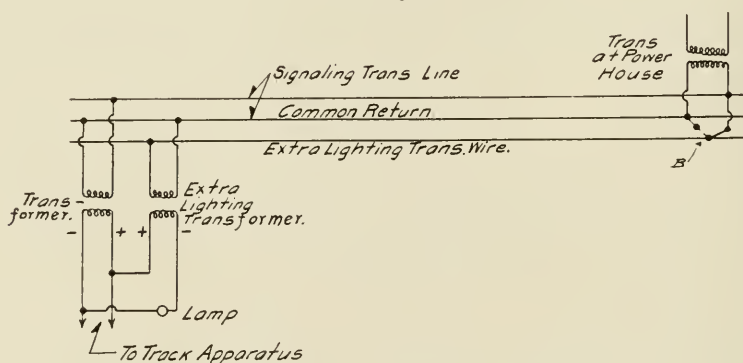
It would be impracticable to reduce the voltage at each individual light signal unless some automatic device could be designed for the purpose. The simplest arrangement is to control the lamp voltage on a section of light signals from the power-house or sub-station, thus placing the control of candle-power in the hands of a station attendant who can vary the candle-power to suit local conditions. The four diagrams, Figs. 55 to 58 inclusive, represent several possible methods of controlling lamp voltage from a sub-station.

Fig. 55 shows a method of voltage control obtained by adding a third wire to the transmission line and an additional transformer for the lamps at each signal location. This additional transformer is to be connected with the third wire, and one of the

signalling mains used as a common return. By varying the voltage between this third wire and the common return at the power-house, the voltage of the lamp can be varied. In this, as in succeeding figures, the term "Track apparatus" is used to designate the track circuits and the relays which in the alternating current system are supplied with power by local transformers connected to the signalling transmission line. These local transformers take the place of the batteries shown in Fig. 2.

Fig. 56 shows a somewhat similar scheme which enables the third wire to be smaller in size than would be required in Fig. 55, and operates as follows: The extra transformer is so wound that its secondary voltage is about one-half that required by the lamps. The secondary of the local transformer is connected in series

FIG. 56.

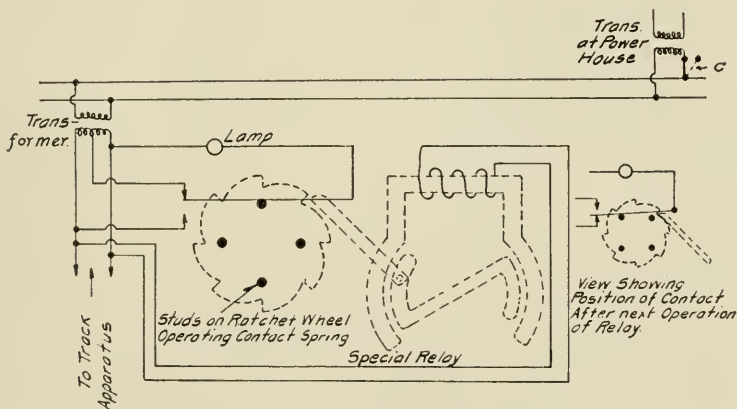


Circuits for controlling voltage at night.

with the secondary of this extra transformer and the lamp. If the power-house attendant short-circuits the third wire and common return by means of a switch *B*, the impedance of the extra transformer is reduced to practically nothing, which applies full voltage of the local transformer to the lamp; if through switch *B* voltage be applied at the power-house between the third wire and the common return, it will induce voltage in the secondary of the extra transformer, which, if the transformers are connected in opposition, reduces the voltage of the local transformer to one-half. The advantage of this scheme over the first one is that the power which is to be transmitted over the third wire is less than when this third wire had to carry all the power for the lamps. The extra transformers can thereby be made smaller in capacity. This reduction in power enables the third wire to be smaller in size.

The third scheme, as shown in Fig. 57, does away with the use of an extra transmission wire and consists of a relay used at each signal location, which by a pawl and ratchet arrangement closes one or the other of two contacts at each alternate operation. These two contacts may be connected to the transformer supplying the lamps, so that when one is closed the lamps receive full voltage; when the other is closed they receive one-half voltage. If all these relays on the signalling section be placed in step, in order to change the voltage the power-house attendant will merely need to open the circuit for an instant by means of a switch *C* and close it again. This will change the voltage on the lamps throughout the system, and in this way, unless an occa-

FIG. 57.



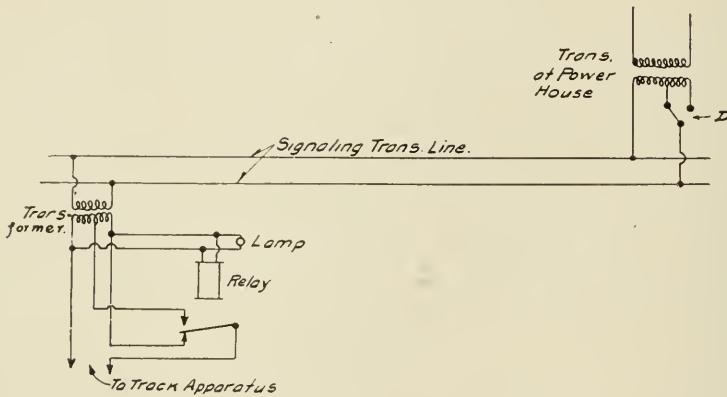
Circuits for controlling voltage at night.

sional relay gets out of step, the power-house attendant has control of all the lamps.

The fourth scheme, which also uses but two transmission wires, operates by varying the high transmission voltage by the percentage of variation desired in the lamps. This would introduce large variations in the track voltage, which in turn means wasted power and decreased safety, as the minimum voltage must be sufficient to operate the track relays, consequently a decided increase in voltage will over-energize the track relays and make it less easy for a train to shunt them and cause relay contacts to open. However, variation in track voltage may be avoided, as shown in Fig. 58, by connecting a relay to the transformer which will have its front contacts closed when high voltage is on the line, and its back contacts closed when low voltage is on the line. By connecting the front contact to the low tap on the transformer

coil which is supplying the track apparatus, and the back contact to the whole coil, it would be possible to maintain the same voltage on the track apparatus, while that of the transmission line would

FIG. 58.



Circuits for controlling voltage at night.

be varied. The transmission line voltage is here shown controlled by a switch *D*.

CHAPTER VIII.

COLOR.

General signalling practice has favored the use of green for clear, yellow for caution, and red for stop. An interesting discussion of color values is presented by Dr. William Churchill in his paper, "The Roundel Problem," page 337 of the 1905 *Proceedings of the Railway Signal Association*. For further reference to the ranges in color and transmission of light the reader is referred to the Railway Signal Association specification for roundels and to the spectro-photometric curves of average intensity signal roundels, and of different illuminants taken from data recently collected and here shown in Figs. 59 and 60.¹

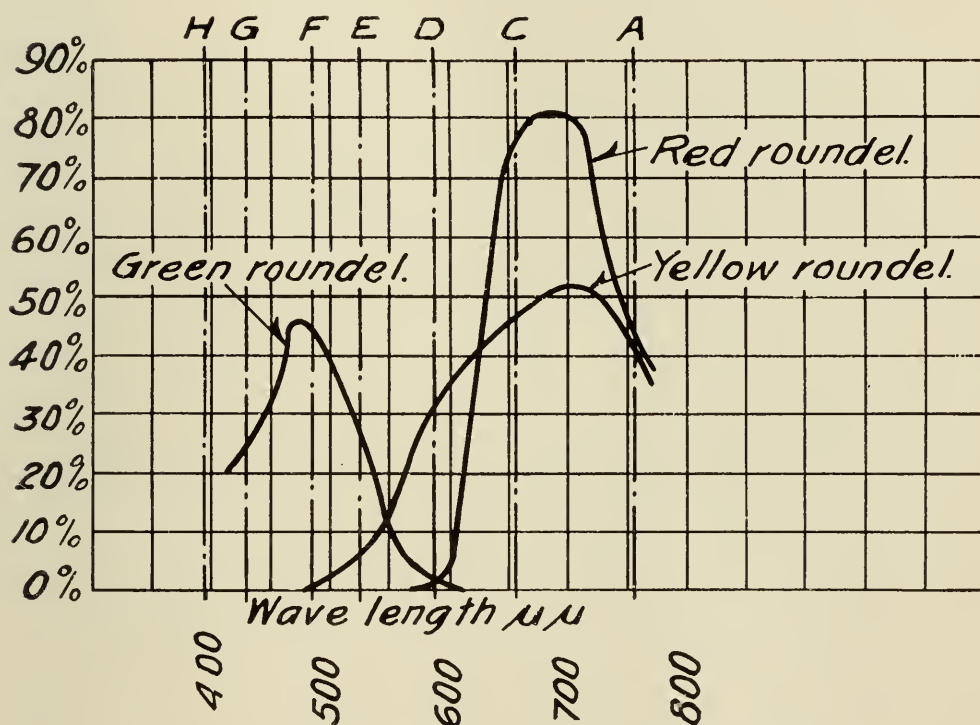
The Railway Signal Association transmission limits—green 75 to 125, yellow 80 to 120, and red 70 to 130—have the endorsement of many years of safe and satisfactory service for night indications of low candle-power. Reference to the Railway Signal specifications will show that standard red, yellow, and green glass are specified having spectro-photometric characteristics similar to the curves in Fig. 59: glass having such specific value is

¹ For information in compiling Figs. 29, 59, and 60 the author is indebted to Mr. Robert E. Morse.

then rated as 100, and roundels or lenses are measured simply by comparing the candle-power transmitted by the sample with that transmitted by the standard. Glass rated as 130 is, therefore, less dense and transmits 30 per cent. more light than the standard.

These limits are based on the oil flame; they have been used with low candle-power tungsten lamps and have apparently given satisfaction, although in theory a denser green and red should be used to compensate for the difference between the spectro-

FIG. 59.



Spectro-photometric analysis of different colored signal roundels.

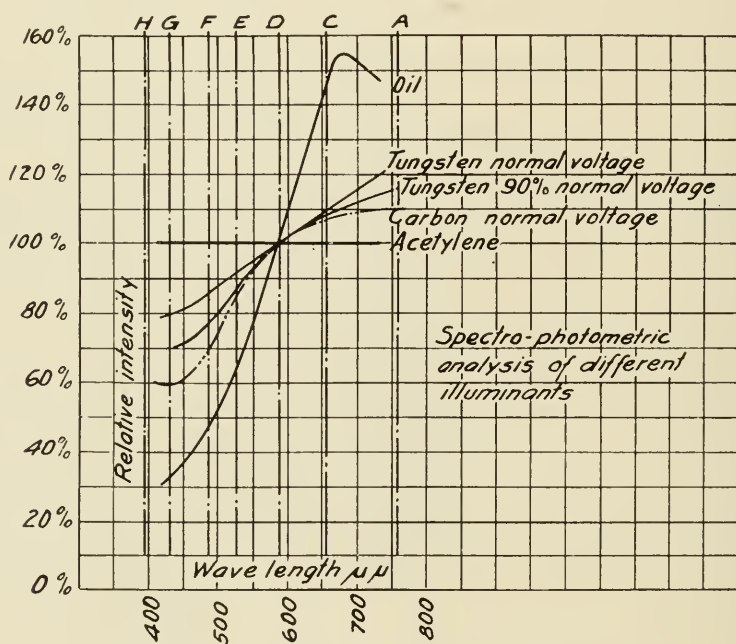
photometric curves of the oil flame and the tungsten filament as shown in Fig. 60. As we are now considering the proper color and transmission of glass for high candle-power signals, using tungsten filament for both day and night indication, some variations in transmission and color are advisable as outlined below.

GREEN.—In daylight, especially against a sky background, the average green shows too weak a color. To get a satisfactory range and fairly well-defined color, a low transmission green has been successfully used. This green will still provide a distinctive color indication at night, even with the high candle-power necessarily used.

RED.—With the candle-power used, average red may verge too closely upon the yellow, especially at twilight or on cloudy days. Experience has shown that an unusually low transmission is useful; even with this dense red it may prove desirable to cut out some of the orange on the *C* line, Fig. 59.

YELLOW.—It is important to get such a distinct yellow that it shall not be possible to confuse it at night with the yellowish light projected by a reflector from a tungsten lamp burning at reduced voltage in case the colored lens or roundel is removed, otherwise a broken red glass might be interpreted by an engineer

FIG. 60.



Spectro-photometric analysis for different illuminants.

as a caution signal; we wish a broken lens or roundel to be obvious and inform the engineer that the signal is out of order, and that he must stop and investigate. For this reason an unusually dense yellow is very desirable. On the other hand, we must be sure that the red is not light or the yellow dense enough to be confused in foggy weather at night or in the early morning. That there is a chance for this is obvious by noting the large amount of red transmitted by the average yellow roundel (see Fig. 59). If yellow and red are similar enough to be mistaken for each other in foggy weather, it may result in an engineer interpreting red as "caution" instead of "stop"—a very dangerous mistake.

By using the very dense yellow and red we increase the power necessary to project a satisfactory signal indication; on the other hand, this added power is necessary to give sufficient range to the green, as unless it is brightly illuminated it presents a very faint indication.

The most obvious advantage of dense colors and high candle-power is the certainty of detecting a broken roundel, there being no danger of mistaking it for a yellow. The increased density also adds to the richness of color, an important consideration in daylight signals.

The use of a position indication has been proposed as a substitute for colors. To present a signal without employing colors it is necessary to use two or more lamps to determine each indication, these lamps being placed behind the proper lenses and being preferably located along the centres of an imaginary semaphore arm so that the different indications will correspond in position to those shown on Fig. 1. The development of the position light signal has not yet reached the stage where any further comment is warranted.

The author would like to consider the relative economy in power secured with low wattage lamps as balanced against the possible increase in operation cost introduced by the more careful attention necessary to secure close alignment or the extra cost of specially constructed lamps. Obviously, each case must be treated on its individual merits; in some cases the high voltage (usually 2200 volts) signal mains will be made so large for mechanical strength that they will readily carry the extra load due to increased lamp wattage without adding anything to the first cost of the installation; and here we have only to consider the increase in operating cost due to power consumed. As this subject cannot be analyzed intelligently without description of various typical installations, the author believes it best to leave further consideration of the subject for future discussion.

CORRECTION.

Figure 63, page 391, April issue, should be figure 54.

Figure 69, page 401, April issue, should be figure 60.

Errors in the Interpretation of Tests for Electrolysis in Iron Pipes. C. HERING. (*Elect. Rly. Journ.*, xlii, 1135.)—It is shown in this article that the interpretation of results obtained by the usual tests for electrolysis on underground metal pipes requires great caution. In a number of cases it is quite easy to draw misleading conclusions unless the conditions are examined with great care. A considerable difference of voltage between adjoining pipes may mean that there is no actual danger, as everything depends on the nature and resistance of the surrounding soil. The so-called "indirect" method, using voltmeter and ammeter, and determining the voltage across the iron pipe both with the ammeter connected and disconnected, is also fallacious; the voltage producing the current may originate at some distant point, and in that case it is easily seen that the resistance of the ammeter itself may seriously affect the figures. Other instances are given where it is shown that the readings, taken by an unskilled observer, are very liable to misinterpretation; and even if this should not be so, there is still to be said that such readings often have no true bearing on the point under examination.

The Testing of Materials. ANON. (*Bur. of Standards, Circ.* 45.)—This circular gives information on the general aspects of the subject valuable to the user or buyer of materials. A brief outline is given with regard to each class of material of the tests usually made, the conditions under which such work is undertaken, and some of the limitations. The classes of materials include metals, cements and concrete, ceramic materials, inks, paper, textiles, rubber, leather, lubricating oils and greases, chemicals and miscellaneous technical materials.

Tobacco Growing in Great Britain. ANON. (*Times*, Aug. 6, 1912.)—The Government has accepted an amendment which exempts from payment of excise duty all tobacco grown in this country by responsible persons under licenses from the Treasury, for the extraction therefrom of nicotine to be used in the preparation of insecticides or otherwise for purely agricultural or horticultural purposes.

Silicon Castings. T. B. ALLEN. (U. S. Pat. 1,073,560.)—Allen purifies the silicon which, made in electric furnaces, contains oxide, oxygen and nitrogen and yields porous castings full of blow-holes, by means of metals which deoxidize and remove nitrogen, such as Ca, Mg, V. The silicon is tapped from an electric furnace into a graphite crucible placed in an oil or coke furnace, in which the silicon is kept fluid for a few hours. From 0.5 to 3 per cent. of Mg is added to the Si in the crucible, until no further reaction is observed. The mould is made of sand and coated with talc. The castings resist acids and are suitable for chemical ware.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE DETERMINATION OF AMMONIA IN ILLUMINATING GAS.

By J. D. Edwards, Bureau of Standards.

THE Bureau of Standards Technologic Paper No. 34 presents the results of a brief investigation of the apparatus and methods employed for the commercial determination of ammonia in illuminating gas. The method generally used for the determination of ammonia in purified illuminating gas depends upon the absorption of the ammonia in a standard acid solution, the amount of ammonia absorbed from a measured volume of gas being determined either by titration of the acid remaining unneutralized or less frequently by allowing the gas to pass until a change is shown by the indicator used.

The choice of the proper indicator to use for this determination is of greater importance than the choice of apparatus. The indicators which were found to be most suitable for the determination of ammonia in gas were sodium alizarinsulphonate, cochineal and paranitrophenol. The presence of glass beads, which are used in some of the absorption apparatus, may lead to erroneous results for two reasons: First, the beads may yield alkali on contact with the absorbing liquid; second, washing of the beads may be incomplete. It is recommended that the operator test the solubility of any beads he may use; the method of washing out the apparatus should also be tested.

Five different forms of apparatus were tested: The Referees apparatus, the Emmerling tower, the Lacy apparatus, the common form of gas wash bottle and a modified form of the Cumming gas bottle. The relative efficiency, and from this the probable accuracy, of the different forms of apparatus were determined by running them in parallel, using gas from a common supply. As a result of this comparison it was found that the Emmerling tower gave results which were somewhat higher than those obtained with the other forms and that the wash bottle gave results

* Communicated by the Bureau.

consistently lower. With careful operation, any one of the five forms of apparatus tested would ordinarily give results that are well within the limits of accuracy required for this determination, either for commercial control work or for the purpose of gas inspection.

ABSTRACT OF THE INFLUENCE OF ATMOSPHERIC CONDITIONS IN THE TESTING OF SUGARS.

By F. J. Bates and F. P. Phelps.

A SIMPLIFIED form of Marvin's evaporation equation has been applied to the evaporation of raw sugar solution during filtration. Marvin's formula reduces to

$$\frac{dq}{dt} = C(P_s - P_a)$$

or $Q = C(P_s - P_a)T$, which, it is shown, fits the observations satisfactorily. Q = the change due to evaporation in the time T ; P_s = the vapor pressure of the sugar solution; P_a = the saturation vapor pressure in the air at the temperature of the dewpoint.

The constant, C , has been determined for a number of different cases: First, when the solution is poured back upon the filter after all has run through; second, when it is poured back after about half has run through; third, when it is not poured back at all. Observations were made by two methods: First, by weighing the solution at intervals during the filtration; second, by observing the change in polarization. In the polarization method one tube was filled, as a reference tube, with solution that had been covered during filtration, since filtration could not be avoided. It is shown, however, by weighing, that the evaporation in this case is quite negligible. Other tubes were filled with solution which had not been covered during filtration. The difference in polarization between these tubes and the reference tube is the change due to evaporation. This was done under various atmospheric conditions.

The observations were made in a thermostated room where the amount of moisture present in the air, as well as the temperature, could be varied at will, the range of adjustment being

$(P_s - P_a) = 4$ mm. of Hg to $(P_s - P_a) = 41$ mm. of Hg. In practice $P_s - P_a$ rarely exceeds 22 mm.

It was found that in the case where the solution was not poured back upon the filter the change in polarization due to evaporation is so small as to be quite negligible in ordinary sugar testing. The change is represented by $Q = 0.00017(P_s - P_a)T$. However, in case that even a portion of the solution is poured back the change due to evaporation is not negligible in ordinary testing but must either be prevented or corrected for.

It may be prevented by covering the funnel, or corrected for by the equation $Q = 0.0006(P_s - P_a)T$.

INDUSTRIAL GAS CALORIMETRY.

FOR many years all laws and regulations relating to manufactured gas were based on candle-power requirements, *i.e.*, the gas burned in a definite burner at the rate of 5 cubic feet per hour was required to give a specified illumination of so many candle-power. This specification furnished a perfectly satisfactory control of the quality of gas delivered so long as the gas was chiefly used for illuminating purposes with the old style of open-flame gas burner. At the present time, however, this inefficient type of burner has been very largely displaced by burners of the Welsbach mantle type. Furthermore, a large amount of the gas sold to-day is used for cooking purposes and to some extent for operating small gas engines for power purposes. In these applications of gas it is the heating value that is of first importance and not the candle-power. It has been estimated that less than 20 per cent. of the gas manufactured and sold to-day, indeed in many of our cities and towns less than 10 per cent., is used in the old type of open-flame gas burners. Notwithstanding this fact we still find in most of our cities and towns ordinances on the statute books requiring that the gas meet a definite candle-power test, while no attention has been given to the question of heating value, which is the important factor for over 80 per cent. of the gas sold. Many of the candle-power requirements fixed by law are quite high, often requiring the manufacture of an expensive oil-enriched gas, which may not be the most economical gas to the public. The importance of the heating value of the gas is now being quite generally recognized, and where new legislation

has been adopted recently and where public-service commissions have considered the question of gas regulation and have gotten to the point of issuing regulations, the heating value standard is being generally adopted, supplemented in some cases by a moderate candle-power standard, the latter with a view to affording the necessary protection to those who still use the open-flame burner.

In view of the growing importance of the question of heating values of gases from the manufacturing, the legislative, the inspecting, and the economic sides, the Bureau of Standards, of the Department of Commerce, started several years ago an exhaustive investigation of the instruments widely used in this country and abroad to measure the heating values of gases, with a view to determining the sources of error to which the instruments are liable, the important precautions to be observed in their use, and the accuracy attainable with them. This investigation has now been completed, and the results will be published in a forthcoming technologic paper, reprints of which may be obtained by those interested in the subject by addressing a written request to that bureau. It is expected that the paper will come from the press about June 1.

Experiments on the Efficiency of Rope Driving. H. BONTE. (*Zeitschr. Ver. Deutsch. Ing.*, lvii, 1711.)—Recently many firms have transformed rope-driving into belt-driving systems, largely on account of the insufficiently criticised results of Kammerer. Experiments on a 200 horse-power plant are described. The ropes used for driving purposes are especially flexible. The efficiency of transmission has a mean value of 97.3 per cent. and increases with the load. The author thinks that few ropes are sufficiently stressed in practice. Rope driving properly applied is quite as efficient as leather belting, and probably more efficient than double or triple belts. It occupies less space and the initial cost is less.

Crystallization through Fatigue of Iron and Steel. F. ROGERS. (*Iron and Steel Inst.*, Sept., 1913.)—The crystalline structure frequently shown by wrought iron or steel which has given way through repeated stress does not appear to be the result of fatigue, since in every case of such failure coming under the author's notice, a fracture of similar appearance could be obtained in an unfatigued part of the metal. Examples of the failure of wrought iron are given in which such crystalline structures, in both the new and the fatigued metal, were due to the presence of low-grade iron or steel scrap.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, April 15, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 15, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 3.

Dr. Allerton S. Cushman, Director, Institute of Industrial Research, Washington, D. C., presented a paper on "Researches in the Metallurgy of Iron." The speaker pointed out the great importance of the problems involved in the production of perfectly sound finished steel and iron. Various methods which have recently been proposed for accomplishing the purpose were reviewed and illustrated, and many of the lecturer's own investigations, as they apply more particularly to the production of very high purity commercial iron, were described for the first time. The bearing of the production of extremely homogeneous metals on the important problems of corrosion was further considered. The subject was illustrated by numerous lantern slides of cross-sections of metals, the various stages of corrosion and of apparatus used in tests and experiments.

After a vote of thanks to the speaker, the meeting adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1913-14.

The number of students enrolled in all Departments of the School this year was 320, an increase of fifteen over the previous year. This enrolment was the largest since the discontinuance in 1899 of the Institute's Branch School at Germantown Junction, which was maintained for several years.

The majority of students registered in one of the four departments of drawing, mathematics, mechanics and naval architecture. Eighteen students were enrolled in two departments, as against sixteen last year.

As heretofore, the largest classes were formed in first-year Mechanical Drawing and Mathematics. Eighty-nine students were admitted to the former of these, and fifty-eight to the latter. There was an exceptionally good representation in all the advanced classes this year; this was particularly the case in the Architectural Drawing and in the Mechanics classes.

Certificates for the satisfactory completion of a two-year course in one

of the four Departments are this year awarded to forty-six students, an increase of two over last year. The good proportion of graduates in Mathematics, Mechanics and Naval Architecture evidenced last year is not only maintained this year, but is bettered; the total number of graduates from these three departments last year was nineteen, while this year it is twenty-two.

On the results of the work of the Winter Term, six students in the Department of Drawing were awarded Scholarships from the B. H. Bartol Fund, entitling them to free tuition in the Spring Term; one student in each of the Departments of Mathematics, Mechanics and Naval Architecture was awarded a Scholarship from the Isaac B. Thorn Fund, entitling him to free tuition in the Spring Term; Certificates of Honorable Mention were also awarded to those students in the respective classes in all Departments who maintained the best attendance and were the most proficient in their work.

On the results of the work of the Spring Term, six students in the Department of Drawing are awarded Bartol Scholarships, and one student in each of the Departments of Mathematics, Mechanics and Naval Architecture is awarded an Isaac B. Thorn Scholarship; these students will be entitled to free tuition during the Winter Term, 1914-15. Certificates of Honorable Mention are also again awarded.

The list of graduates for the season 1913-14, as well as of recipients of the above honors, and of the following special prizes awarded on the results of the year's work, is appended hereto:

Mr. J. B. McCall's Prize for Mathematics.

Mr. Wilfred Lewis's Prize for Mechanics.

The New York Shipbuilding Co.'s Prize for Naval Architecture.

The Alumni Association of The Franklin Institute's Prizes awarded to the most proficient students in each Department.

In conclusion, I desire to express my sincere appreciation of the continued co-operation of Mr. Wm. E. Bullock, Assistant Director, and Messrs. Clement Remington, Frank H. Lobb, I. P. Pedrick, Chas. Rommel, W. W. Twining, H. P. Tyson, Elmer Bark, and H. C. Towle, and of the work of Messrs. John F. Allison and W. A. Van Osten appointed this year.

WM. H. THORNE,
Director.

LIST OF GRADUATES, ETC., 1913-14.

MECHANICAL DRAWING.

James P. Cavanagh	Harry J. Schmidt
Jonathan Cleaver, Jr.	Maurice Raymond Shultz
Raymond J. Davies	Charles P. Smith
James R. Edmiston	Fred W. Sperling
Albert Forster	Arthur L. Stettler
Chester Gable	Julius Uhrmann
Leon Liberman	Arthur Charles Vickery
Frank E. McDonnell	Harry L. Wells
George S. Moore	

ARCHITECTURAL DRAWING.

W. Hammond Fletcher	Rudolph Lukens
Louis Gorohowsky	Garnier Walz
Percival Lukens	

FREEHAND DRAWING AND WATER COLOR.

William H. Cameron	Walter E. Jones
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MATHEMATICS.

Harry H. Bonner	John D. Masterson
James P. Cavanagh	Walter Merkh
Benjamin Cheesman	Edward J. Moran
H. Arthur Grosscup	Ellwood A. Smith
Harry G. Lloyd	Joseph E. Walters

MECHANICS.

Harry W. Barnhurst	William M. Meinel
William D. Eastwood	J. F. Pfeffer
George M. Harrison	Arnold Rogers

NAVAL ARCHITECTURE.

James S. Bowen	Willis M. Hayden
Thomas Devine	Einar Jentoft
S. W. Garrigues	William E. Taylor

BARTOL SCHOLARSHIPS.

WINTER TERM.

Wm. Henry Clarke	Frank Long
Harry Haering	Warren G. Tilton
Benjamin Lamb	Alfred G. Windstein

SPRING TERM.

Gordon N. Davis	Harry Haering
Louis Gorohowsky	Welling G. Schrack
Howard A. Gaul	Fred Stadtler

ISAAC B. THORN SCHOLARSHIPS.

WINTER TERM.

Emil C. Schneider	Thomas Devine
James G. Morgan	

SPRING TERM.

John G. Merkh	Thomas Devine
Harry N. Rahn	

MR. J. B. McCALL'S PRIZE.

MATHEMATICS.

Ellwood A. Smith

MR. WILFRED LEWIS'S PRIZE.

MECHANICS.

William M. Meinel

THE NEW YORK SHIPBUILDING COMPANY'S PRIZE.

NAVAL ARCHITECTURE.

Lawrence Hoban

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE.

GRADUATES AWARDED PRIZES BY THE ASSOCIATION.

Raymond J. Davies,
Mechanical DrawingLouis Gorohowsky,
Architectural DrawingWalter E. Jones,
Freehand DrawingEdward J. Moran,
MathematicsGeorge M. Harrison,
MechanicsWilliam E. Taylor,
Naval Architecture

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
April 1, 1914.)*HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 1, 1914.MR. J. A. P. CRISFIELD *in the Chair.*

The following reports were presented for final action:

No. 2541.—Guillaume's Alloy "Invar." John Scott Legacy Medal
and Premium. Recommendation adopted.No. 2596.—Hirsch's Electric Safety Lamp. Edward Longstreth
Medal of Merit. Adopted.

The following reports were presented for first reading:

No. 2585.—Ridgway's Steam-Hydraulic Elevator.

No. 2589.—Nitrogen-Filled Tungsten Lamps.

Recommendation Deferred. Advisory. Adopted.

The following application for investigation was accepted:

No. 2605.—Blonck Efficiency Meter.

The following subject was recommended for examination:

No. 2506.—John W. Hyatt's Researches Leading to the Establishment
of the Nitrocellulose Industry.R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A joint meeting of the section and of the Aero Club of Pennsylvania was held in the Hall of the Institute on Thursday evening, March 26, 1914, at eight o'clock.

Dr. Walton Clark, President of the Institute, and Mr. Clarence P. Wynne, President of the Aero Club, presided jointly.

The minutes of the previous meeting were approved as published.

Dr. Clark introduced Lieut.-Colonel Samuel Reber, U. S. A., in charge of the aeronautical work of the Signal Corps, who delivered a lecture entitled "Recent Progress in Military Aeronautics." By means of numerous lantern slides of the latest types of dirigibles and aeroplanes, the lecturer illustrated the present aeronautical equipment of the troops of the principal nations. He developed the necessity and importance of a suitable air force in war, and gave instances of the utility of such a force in northern Africa and in the recent war in the Balkans. He spoke of the backwardness of the United States in military aeronautics, attributing this to a lack of interest both on the part of Congress and of the people at large. He urged an awakening of the popular interest in what should, he thought, be one of our principal means of defense.

The remarks of the speaker were discussed by several members present, and the thanks of the meeting were then extended to Colonel Reber.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, April 2, 1914, at eight o'clock.

Mr. G. R. Henderson, President of the section, presided.

The minutes of the previous meeting were approved as published.

The chairman introduced Mr. John A. Vogleson, President of the Board of Health and Chief of the Bureau of Health of the City of Philadelphia, Member of the Institute, who delivered a lecture entitled "Some Engineering Problems in Sanitary Science," in which he demonstrated what has been done to promote sanitary conditions with the object of reducing communicable diseases in the city of Philadelphia.

The lecture was illustrated by means of lantern slides. After discussion by members present, the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Electrical Section.—A meeting of the section and the Illuminating Engineering Society was held in the Hall of the Institute on Thursday evening, April 9, 1914, at 8 o'clock.

Dr. George A. Hoadley occupied the chair.

The minutes of the previous meeting were approved as published.

The chairman introduced Mr. Preston S. Millar, of the Electrical Testing Laboratories, New York City, who delivered a lecture entitled "Recent Developments in the Art of Illumination." In his lecture, the speaker indicated the efforts made in the last few years to improve artificial lighting and described the present status of pending developments in the illuminating art.

The speaker's remarks were discussed by members present, and the thanks of the meeting were then extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting, Board of Managers, March 11, 1914.)

RESIDENT.

MR. S. PEACOCK, 5911 Washington Avenue, Philadelphia.

MR. ARTHUR J. RHOADES, Pennsylvania Salt Works, Philadelphia.

NON-RESIDENT.

MR. ELWOOD GRISSINGER, 924 White Building, Buffalo, New York.

Changes of Address.

MR. A. B. BEADLE, New Hartford, Connecticut.

MR. A. S. KREBS, 115 Ridgewood Road, Ithaca, New York.

MR. ISHAM RANDOLPH, 1827 Continental and Commercial National Bank Building, Chicago, Illinois.

MR. V. A. SUYDAM, University of Mexico, Albuquerque, Mexico.

NECROLOGY.

Mr. Charles W. Close, Philadelphia.

Mr. George E. Kirkpatrick, Philadelphia.

LIBRARY NOTES.

Purchases.

ALLEN, H. S.—Photo-electricity, Liberations of Electrons by Light. 1913.
American Electrochemical Society.—Transactions, vol. 24. 1913.

BEIN, W.—Comp. Otto v. Guericke, ueber die luft pumpe und den luft druck.
1912.

- Engineering Index.—Annual 1913. 30th year.
HENRIET, E.—Manuel pratique de surrurerie. 1914.
Hero of Alexandria, Works.—5 vols. 1899-1912.
HISCOX, G. D.—Henley's Twentieth Century Formulas, Receipts. 1914.
International Congress for Testing Materials. Proceedings of 6th Congress.
1912. 2 v.
KONEN, HEINRICH.—Das Leuchten der Gase und Dämpfe. 1913.
LONES, T. E.—Aristotle's Researches in Natural Science. 1912.
MACKENZIE, J. E.—The Sugars and Their Simple Derivatives. 1914.
MOUREAU, CHARLES.—Notions fondamentales de chimie organique. 1913.
OSTWALD, WILHELM.—Werdegang einer Wissenschaft. 1908.
OWEN, DAVID.—Recent Physical Research. 1913.
PAINE, P. M., and STROUD, B. K.—Oil Production Methods. 1913.
PERRIN, JEAN.—Des atomes. 1913.
PHILLIPS, FRANCIS C.—Chemical German. 1913.
SHEPPARD, S. E.—Photo-chemistry. 1914.
SMITH, ERNEST A.—Sampling and Assay of the Precious Metals. 1913.
STANFIELD, ALFRED.—The Electric Furnace. 1914.
Taschenbuch der Luft flotten. 1914.
Thomas' Register of American Manufactures. Sixth ed. 1914.
THOMSON, SIR J. J.—Rays of Positive Electricity, and Application to Chemical Analysis. 1913.
TILDEN, SIR W. A.—Progress of Scientific Chemistry in Our Own Times. 1913.
WELLS, M. B.—Steel Bridge Designing. 1913.

Gifts.

- Alabama Geological Survey, Bulletins 13 and 14 and Monograph 8. University, 1913. (From the Survey.)
All About Colorado. Denver, Colo., 1913. (From Mr. L. C. Phipps.)
Bureau for the Safe Transportation of Explosives. Report of the Chief Inspector, 1914. New York, 1914. (From the Chief Inspector.)
Canada Department of Mines, Annual Report on the Mineral Production of Canada, 1912. Geological Survey. Guide Books, Nos. 5, 8; pts. 1-3; 9, 10. Ottawa, 1914. (From the Department.)
Canada Department of Trade and Commerce, Report, 1913, pt. 1. Ottawa, 1914. (From the Department.)
Central University of Kentucky, Catalogue of the Central College, 1913-1914. Danville, 1914. (From the University.)
Danish Beer and Continental Beer Gardens, by Dr. Max Henius. New York, 1914. (From the United States Brewers' Association.)
Fairmount Park Art Association, 42nd Annual Report. Philadelphia, 1914. (From the Association.)
General Society of Mechanics and Tradesmen, 124th Annual Report, 1913. New York, 1914. (From the Society.)
Georgetown University, Catalogue 1913-1914. Washington, D. C., 1913. (From the University.)

- Hobart College, Catalogue 1913-1914. The Installation of Lyman Pierson Powell as President; November 14, 1913. Geneva, N. Y., 1914. (From the College.)
- Institution of Engineers and Shipbuilders in Scotland, Transactions, vol. 56. Glasgow, 1913. (From the Institution.)
- Medford Water and Sewer Commissioners, Annual Report, 1913. Medford, Mass., 1914. (From the Commissioners.)
- Metropolitan Sewerage Commission, Preliminary Reports on the Disposal of New York's Sewage, Nos. 11-16. New York City, 1914. (From the Commission.)
- Michigan Agricultural Experiment Station, 26th Annual Report. Lansing, 1913. (From the Station.)
- Michigan State Public Domain Commission, Report, January, 1911-June, 1913. Lansing, 1914. (From the Commission.)
- Missouri Bureau of Geology and Mines, vol. 12 (second series); The Geology of the Rolla Quadrangle. Jefferson City, n. d. (From the Bureau.)
- Mysore Meteorological Department, Report on Rain Fall Registration in Mysore, 1912. Bangalore, 1914. (From the Department.)
- North Dakota Geological Survey, Sixth Biennial Report. Bismarck, 1912. (From the Survey.)
- Nova Scotia Department of Mines, Report, 1913. Halifax, 1913. (From the Department.)
- Ontario Department of Agriculture, Vegetable Growers' Association, 9th Annual Report, 1913. Agricultural Societies, Appendix to Annual Report, 1913. Toronto, 1914. (From the Department.)
- Pennsylvania Board of Commissioners of Public Charities, 43rd Annual Report, 1912; Factory Inspector, 23rd Annual Report, 1912; Forty-seventh Annual Encampment of the Grand Army of the Republic, 1913; Smull's Legislative Hand-Book, 1913. Harrisburg, 1914. (From the State Librarian.)
- Pennsylvania Prison Society, The Journal of Discipline, March, 1914. Philadelphia, 1914. (From the Society.)
- Piano and Organ Purchaser's Guide for 1914. New York City, 1914. (From The Music Trades Co.)
- Pittsburgh, Cincinnati, Chicago & St. Louis Railway Co., 24th Annual Report, 1913. Pittsburgh, 1914. (From the Company.)
- Pittsburgh Flood Commission, Report, 1911. 2 vols., N. p., n. d. (From Mr. John Birkinbine.)
- R. Accademia Delle Scienze Dell'Istituto Di Bologna. Memorie, Tomo 9, pts. 1-4. Rendiconto, vol. 16. Bologna, 1912. (From the Institute.)
- Rose Polytechnic Institute, 32nd Annual Catalogue. Terre Haute, Ind., 1914. (From the Institute.)
- Royal Philosophical Society of Glasgow, Proceedings, vol. 44. Glasgow, 1913. (From the Society.)
- Syracuse University, Catalogue, March, 1914. Syracuse, N. Y., 1914. (From the University.)
- Taunton Water Board, Report for 1913. Taunton, Mass., 1914. (From the Board.)

University of Toronto, Calendar, Faculty of Applied Science and Engineering, 1914-1915. Toronto, Can., n. d. (From the University.)

University of Vermont, Catalogue, 1913-1914. Burlington, 1914. (From the University.)

Ursinus College, Catalogue, 1913-1914. Collegeville, Pa., 1914. (From the College.)

Washington Public Service Commission, 3rd Annual Report. Olympia, 1913. (From the Commission.)

PUBLICATIONS RECEIVED.

Karbide und Silizide, von Prof. Dr. Otto Höning Schmid. 263 pages, illustrations, 8vo. Halle (Saale), Wilhelm Knapp, 1914. Price, in paper, 18.60 marks.

A Laboratory Guide to the Study of Qualitative Analysis Based upon the Application of the Theory of Electrolytic Dissociation and the Law of Mass Action, by E. H. S. Bailey, Ph.D., and Hamilton P. Cady, Ph.D. Seventh edition, 280 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1914. Price, \$1.25.

Animal Flight. A record of observation, by E. H. Hankin, M.A., Sc.D. 412 pages, illustrations, 8vo. London, Iliffe & Sons, 1913. Price, 12 shillings and 6 pence.

Designing and Detailing of Simple Steel Structures, by Clyde T. Morris, C.E. Third edition, revised and reset. New York, McGraw-Hill Book Co., 1914. Price, in cloth, \$2.25.

U. S. Bureau of Standards, Scientific Paper No. 213. Critical Ranges A_2 and A_3 of Pure Iron, by G. K. Burgess and J. J. Crowe. (Reprinted from Bulletin of Bureau of Standards, vol. 10.) 53 pages, plates, 8vo. Washington, Government Printing Office, 1914.

Canada Department of Mines, Mines Branch. Researches on Cobalt and Cobalt Alloys, Conducted at Queen's University, Kingston, Ontario. Part I. Preparation of Metallic Cobalt by Reduction of the Oxide, by H. T. Kalmus, B.Sc., Ph.D., assisted by C. W. Day, M.A., C. Harper, B.A., W. L. Savell, B.Sc., and R. Wilcox. 36 pages, illustrations, plates, 8vo. Ottawa, Government Printing Office, 1913.

Philadelphia, Department of City Transit, Rapid Transit Development with Universal Free Transfers. Reply of the Department of City Transit to Proposals of March 25, 1914, by the Philadelphia Rapid Transit Compny. 22 pages, 8vo. Philadelphia, April 7, 1914.

U. S. Bureau of the Census, Forest Products: Lumber, Lath, and Shingles, 1912. Compiled in Coöperation with the Department of Agriculture Forest Service, Henry S. Graves, Forester. 60 pages, 8vo. Washington, Government Printing Office, 1914.

The Postalization of the Telephone and the Telegraph, Speech of Hon. David J. Lewis, of Maryland, in the House of Representatives, January 16, 1914. 15 pages, 8vo. Washington, 1914.

U. S. Department of Agriculture, Bulletin No. 55, Professional Paper,

Balsam Fir, by Raphael Zon, Chief of Forest Investigations. 68 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1914. Price, ten cents.

U. S. Coast and Geodetic Survey. Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, 1911 and 1912, by Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 100 pages, tables, plates, 4to.

Terrestrial Magnetism. Results of Magnetic Observations Made by the United States Coast and Geodetic Survey between July 1, 1911, and December 31, 1912, by R. L. Faris, Inspector of Magnetic Work; Assistant, Coast and Geodetic Survey. Special Publication No. 15, Washington, Government Printing Office, 1913 and 1914.

U. S. Bureau of Mines, Bulletin No. 42. The Sampling and Examination of Mine Gases and Natural Gas, by George A. Burrell and Frank M. Seibert. 116 pages, illustrations, 8vo. Bulletin 68, Electric Switches for Use in Gaseous Mines, by H. H. Clark and R. W. Crocker. 38 pages, plates, 8vo. Technical Paper No. 57, Petroleum Technology 13, a Preliminary Report on the Utilization of Petroleum and Natural Gas in Wyoming, by W. R. Calvert, with a discussion of the Suitability of Natural Gas for Making Gasoline, by George A. Burrell. 23 pages, 8vo. Technical Paper No. 69, Production of Explosives in the United States During the Calendar Year 1912, compiled by Albert H. Fay. 7 pages, 8vo. Technical Paper No. 71, Permissible Explosives Tested Prior to January 1, 1914, by Clarence Hall. 12 pages, 8vo. Washington, Government Printing Office, 1913-1914.

Scanes' Vacuum Efficiency and Absolute Pressure Gauge. A. E. L. SCANES. (*Mech. Eng.*, xxxii, 457.)—The principle of this efficiency gauge is that for a given water temperature there is an absolute vapor pressure. If a glass U-tube, sealed at one end, is exhausted of air and partially filled with water, heated to the temperature of the condenser circulating discharge, then on connecting the open end to the condenser vacuum the water in the U-tube will show, by the difference of levels, a measure of the "condenser" efficiency. A similar arrangement heating the water-tube to condensed steam temperature will represent "vacuum" efficiency. The former of these indications will vary with the condition of the condenser tubes, and the latter with the proportion of air not removed by the air-pump. Should the vacuum decrease while both efficiencies are normal the cause can only be too little circulating water, or its too high temperature. The instrument devised by the author with an improved absolute pressure gauge is described and illustrated.

CURRENT TOPICS

Inflammability of Coal Dust. J. C. W. FRAZER, E. J. HOFFMAN and L. A. SCHOLL, JR. (*Bureau of Mines*, Bull. 50, 1913.)—The dust is exploded in a spherical bulb of 1.6 litres capacity provided with two tubular necks. The one above is closed by a brass plate, into which a brass tube, 7 mm. diameter, is soldered, rising vertically; on top of this tube rests a vessel charged with mercury; this vessel (or pressure valve) is raised by the explosion pressure, which can be determined within 5 grammes by a few experiments. The coal dust is blown into the bulb through a tube, opening out into a funnel, which passes through the lower neck. Ignition is effected by a coil of platinum wire suspended in the vessel. The pressure valve is opened at intervals of 1, 2 and $2\frac{3}{4}$ minutes after closing the circuit in order to let the warm air escape, and the charge of 0.05 gramme of coal dust is blown into the bulb at the end of the third minute. Many samples of coal from different mines and of coal dusts from mine roads were tested in this way; also coal dusts mixed with stone dusts and other dusts. The many curves reproduced plot the pressure (in grammes for the tube of 7 mm.) against the current intensities which ranged from 5 to 7 ampères. With pure coal the pressure rose in most cases to 250 grammes, either steadily, or slowly at first and then rapidly to something like a maximum. The addition of stone dust (shale or calcium carbonate) lowered the pressure; but 10 or even 20 per cent. of stone dust had little effect in this respect, and ignition always occurred with the maximum percentage (50) of stone dust used. The other materials tested were various woods (pine, oak, mahogany), asphalt, sugar and lycopodium. Analyses of the coals, stating the moisture, volatile matter, fixed carbon, ash and sulphur, are given.

Danger Signals at Grade Crossings. ANON. (*Sci. Amer.*, cix, No. 22, 407.)—The Lehigh Valley Railroad is installing, at highway grade crossings, danger signals which should prove to be very effective. As soon as a train comes within a mile of a crossing, the signal shows a red light and a gong which can be heard 500 yards away begins to ring. Both warnings continue to act until the train has passed, when the gong ceases and the red light changes to white. If the wires become deranged, or should anything happen to the mechanism, the signal on the disc flashes to danger and remains there till repairs are made. Nothing short of demolition can prevent the signal from working.

Nitrate Industry of Chile. ANON. (*Oil, Paint and Drug Reporter*, Dec. 8, 1913.)—According to the annual report of the Nitrate Propaganda Association, the total production of sodium nitrate in Chile during 1912 was 2,885,959 short tons, as compared with 2,784,361 tons in 1911. Exports from the whole district in 1912 were 2,753,500 tons as compared with 2,705,382 tons in 1911, 2,579,945 tons in 1910, and 2,357,968 tons in 1909. During last year the United States received about 500,000 tons of the product. Germany received about 600,000 tons, and the United Kingdom 1,000,000 tons out of the total listed exports. Of iodine the United States took 183 tons, as against 264 tons to European countries and 65 tons to the United Kingdom. Considerable progress has been made in the use of oil as fuel for boilers in the oficinas, and it is said to effect a saving of about 40 per cent. It is proposed to carry out experiments on a large scale, with a view to discover a method of treating low-grade caliche.

Feed Water Heating. ANON. (*Sci. Amer.*, cix, No. 24, 451.)—The new Brooke high velocity feed water heaters are said to deliver water 20 degrees hotter than the usual heaters and save considerable fuel. When working with exhaust steam it is known that heaters rarely deliver water hotter than 170° to 180° F. when working at maximum capacity. With the new system the temperature reaches 200° F. Such heaters are made in vertical and horizontal types and work equally well on live and exhaust steam, a very economical arrangement being to have an exhaust and live steam heater working in conjunction.

Production of Pyrite and Sulphuric Acid in 1913.—The production of pyrite in the United States in 1913, according to W. C. Phalen, of the United States Geological Survey, was 341,338 long tons, valued at \$1,286,084. For 1912 the output amounted to 350,928 long tons, valued at \$1,334,259, a decrease for 1913 in quantity of 9590 long tons and in value of \$48,175. The production in the leading States—Virginia and New York—diminished slightly, in California there was an increased production, and in Wisconsin the output also continued to increase. The output of by-product pyrite, obtained in connection with coal mining, fell off materially.

Imports of Pyrite.—The imports of pyrite for consumption during the calendar year 1913 were 850,592 long tons, valued at \$3,611,137. These figures show a notable decrease in quantity of 120,193 long tons, and in value of \$230,546, as compared with the imports in 1912, which amounted to 970,785 long tons, valued at \$3,841,683.

Production of Sulphuric Acid.—According to actual returns for the year 1913 the production of sulphuric acid in the United States was 3,538,980 short tons of 50° acid, valued at \$22,366,482. This output does not include a small amount of fuming acid, but does

include by-product acid—that is, acid obtained in the smelter industry. The acid produced at copper and zinc smelters in 1913 amounted to 790,296 short tons of 50° acid, valued at \$4,346,272. The production of acid by grades is tabulated in detail below:

PRODUCTION OF SULPHURIC ACID IN THE UNITED STATES IN 1913, BY GRADES, IN SHORT TONS.

<i>Grade.</i>	<i>Quantity.</i>	<i>Value.</i>	<i>Price per ton.</i>
50° Baumé	1,643,318	\$9,212,917	\$5.61
60° Baumé	509,929	3,202,528	6.28
66° Baumé	797,104	9,282,422	11.65
Other grades	63,158	986,659	15.62
Total	3,013,509	\$22,684,526	\$7.53
Total reduced to 50° Baumé acid ¹	3,538,980	\$22,366,482 *	\$6.32

PRODUCTION OF SULPHURIC ACID FROM COPPER AND ZINC SMELTERS IN 1911, 1912 AND 1913, IN SHORT TONS (60° Baumé Acid).²

Source.	1911.			1912.			1913.		
	Quantity.	Value.	Price per ton.	Quantity.	Value.	Price per ton.	Quantity.	Value.	Price per ton.
Copper smelters.	207,657	\$1,056,185	\$5.09	321,156 ³	\$1,985,704 ³	\$6.18 ³	336,019	\$2,205,627	\$6.56
Zinc smelters....	230,643	1,677,511	7.27	292,917 ³	2,255,237 ³	7.70 ³	296,218	2,140,645	7.23
Total.....	438,300	2,733,696	6.24	614,073 ³	4,240,941 ³	6.91 ³	632,237	4,346,272	6.78
Total acid reduced to 50° Baumé	547,875	.....	.....	764,237 ⁴	.....	.....	790,296	.....	.....

The year 1913 is the third for which the Survey has collected statistical information on the sulphuric acid industry in the United States. The Survey's figures are not estimates but are compiled from first-hand information received from the producers themselves and cannot exceed actual production.

The above figures are final, so far as the Survey's present information goes, but they are subject to change if necessary when the printed report is issued. The changes, if any are made, will probably be slight.

¹ Exclusive of a small amount of fuming acid.

² The acid reported to the Survey includes that of strength of 50°, 53°, 60°, and 66° Baumé, and a small quantity of electrolyte and oleum. All strengths, with the exception of the electrolyte, have been reduced to both 50° and 60° Baumé, as given in the table.

³ Inclusive of a small quantity of electrolyte.

⁴ Exclusive of a small quantity of electrolyte.

Production and Use of Denatured Alcohol in Principal Countries.—Germany now uses between forty and fifty million gallons of denatured alcohol a year, of which over thirty million gallons are sold to the general public for burning purposes. The importance of this fuel in Germany may be appreciated when it is considered that France uses about eighteen million gallons, the United States about ten million gallons, and the United Kingdom only four million gallons, according to a monograph by Charles A. Crampton, commercial agent of the Department of Commerce, recently issued by the Bureau of Foreign and Domestic Commerce. Denatured alcohol is not only gaining in favor for general burning purposes, but a determined effort is being made to find a way of using it as a motor fuel in place of a high-priced gasoline. All the recent developments are dealt with in the new monograph, which is entitled "Production and Use of Denatured Alcohol in Principal Countries" (Special Agents' Series, No. 77). Copies at five cents each may be had from the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Propagation of Electric Waves.—The effect of solar eclipses on the propagation of electric waves will be investigated by the British Association for the Advancement of Science during the total eclipse of the sun which will take place August 21, 1914. It was observed during the solar eclipse of April 17, 1912, that the strength of wireless signals was greater during the eclipse than an hour before or after. To investigate the propagation of signals across the umbra, it will be necessary to arrange for wireless telegraph stations on either side of the central line of the eclipse to transmit signals at intervals while the umbra passes between them. This transit of the umbra occupies about two minutes, therefore it is very desirable that the Scandinavian and Russian stations should transmit frequently throughout several minutes before, during, and after totality. The eclipse will be total along a strip extending from Greenland across Norway, Sweden, Russia and Persia to the mouth of the Indus. The Committee of Radiotelegraphic Investigation of the British Association have arranged with wireless stations all over the world for exchange and observation of signals during the eclipse.

Active Nitrogen. E. TIEDE and E. DOMCKE. (*Ber.*, xlv, 4095.) —Further experiments have confirmed the view expressed previously, that the yellow after-glow considered by Strutt to mark the re-formation of ordinary nitrogen from an active modification produced by the action of electric discharges, is due to the presence of a small quantity of oxygen, and indeed forms an exceedingly sensitive test for the presence of traces of oxygen in nitrogen. An apparatus is described in which pure nitrogen can be generated by heating barium azide in a vacuum and then it is subjected to the electric discharge.

Bureau of Standards' Analyzed Samples.—The Bureau of Standards is prepared to issue purified dextrose as a standard reducing sugar. The substance is free from ash and contains less than 0.1 per cent. of moisture. In an atmosphere of average humidity it is slightly hygroscopic, but if dried at 70° C. it retains less than 0.1 per cent. of moisture. A certificate of analysis showing the quantity of remaining impurity accompanies the sample. The purpose of the standard is to assist in the unification of reducing sugar analysis by supplementing or replacing the use of invert sugar. It is also available for general sugar work.

The fee, payable in advance, is \$2 for 70 grams or \$3 for 140 grams.

Further information may be obtained in Circular 25 on Standard Samples or Circular 44 on Polarimetry.

Electrolysis of Buried Lead and Iron. GIROUSSE. (*Comptes Rendus*, clvii, 705.)—With a view to suppressing wandering currents capable of attacking water or gas pipes or cable sheathings, the voltage drop in tram rails is limited, in France, to 1 volt per kilometre. It is suggested that what should be specified is the potential difference between rails and metal liable to electrolytic attack. To determine what was the critical potential difference below which attack could not occur, experiments were made with soil taken, (*A*) from a place remote from electric tram lines, (*B*) from a place where serious electrolytic damage had occurred. The samples contained siliceous sand, a high percentage of aluminum silicate and calcium carbonate, with appreciable amounts of calcium sulphate and nitrate and sodium chloride. Loss of weight on incineration, 16 per cent. in case of (*A*); 22 per cent. in case of (*B*). Electrodes of iron and lead (1 mm. thick, 1 sq. dm. area) were placed at opposite sides of boxes containing about 1 cubic dm. of the soils investigated; all the negative and half the positive electrodes were of iron; the remaining positives were lead. Potential differences of 0.1, 0.2 up to 1.0 volt were established between the electrodes in various troughs, and control troughs were arranged to make possible allowance for simple chemical attack. About 20 grammes of water were added daily to each trough, corresponding to 70 cm. annual rainfall; temperature was maintained at about 16° C. The resistance of dry soil was found to be almost infinite, but that of very moist soil fell to 10³ ohms/cm.; after watering for some weeks, the resistance fell to 600 ohms/cm. at the moment of applying potential difference, and to 2500 ohms/cm. after several months' electrolysis. The contact resistance between electrodes and the earth varied inversely with the surface area, and lead offered a much higher contact resistance than iron; between iron = iron 11 times as much current flowed as between lead = iron. Soil and contact resistance were independent of electromotive force and current density within the limits of the tests (16 volts and 0.01 amp./dm.²). Between lead and iron on

open circuit there was a potential difference of 0.15 to 0.2 volt from lead to iron. When current flowed through the test troughs, lead nitrate and carbonate formed on the lead; the iron plates were attacked much more vigorously, and ferric hydrate with traces of ferrous oxide was found in the surrounding soil. The composition of the soil had an important bearing on the loss of weight per ampère-hour in cases (*A*) and (*B*) respectively; approximate data are 1.6 grammes and 2.88 grammes lead, and 1.33 grammes and 0.89 gramme iron per ampère-hour. The conclusion reached is that iron pipes are attacked electrolytically if they are positive to return rails; before lead is thus attacked, a critical potential difference of 0.2 volt must be exceeded; in any particular case, lead is attacked much less readily than iron.

The Toxic and Antiseptic Properties of Paints.—At the Thirtieth Annual Convention of the International Association of Master House Painters and Decorators of the United States and Canada, Mr. Henry A. Gardner, Assistant Director of The Institute of Industrial Research, Washington, D. C., read a paper on The Toxic Effect of Pigments. The paper included chapters on the Composition and Toxicity of Oil Paint Vapors; Cause and Prevention of Toxic Effect of Pigments; and The Relative Toxicity of Volatile Thinners. The Summary of Conclusions was as follows:

Lead poisoning may occur through the inhalation of the dust from dry lead pigments, or by the careless handling and hand-mixing of lead paints. It may be prevented by establishing more cleanly and sanitary working conditions, through observance of the rules of personal hygiene, and by the adoption and use of prepared paint products.

Drying oil paints do not evolve metallic vapors. They do, however, give forth small quantities of carbon monoxide gas. Paints also emit in vaporous form the volatile products used as thinners. Of these products, benzol is most dangerous, while high boiling-point petroleum spirit is least harmful. With proper ventilation the fumes from drying paints are diluted and dissipated by the atmosphere so that they become harmless.

Drying oil paints evolve aldehydes and other germicidal substances in vaporous form. The antiseptic effect of such vapors is pronounced. The application of oil paints is therefore to be considered as one of the most efficient means of rendering living and sleeping rooms thoroughly sanitary.

CORRECTION.

"The Present Physical Knowledge of X-Rays," by Wheeler P. Davey, March, 1914, page 293.

Reference No. 6, page 294, should read: "J. de Beaujeu, Arch. d'Elect. Med., May 25, 1910.

The Future of Oil Fuel. B. REDWOOD. (*J. Roy. Soc. Arts*, lxii, 103.)—The world's output of petroleum has increased from 22,000,000 metric tons in 1901 to 46,500,000 metric tons in 1911, or from 2.8 to 4.3 per cent. of the world's output of coal. The United States supplies about 63 per cent. and Russia about 19 per cent. of the total output, the remaining 18 per cent. is supplied by Mexico, Roumania, Dutch East Indies, Galicia, India, and about $1\frac{1}{2}$ per cent. from other countries. The demand is increasing more rapidly than the supply, and the course of future developments depends on the extent to which supplies can be increased, and also upon the way in which the oil is used. The supply from Russia is likely to increase, as there are large areas still undeveloped. The supply from Mexico will become much greater, but it may be entirely absorbed by the United States. There has been a great increase of production in California, which State is being rapidly transformed from an agricultural to a manufacturing country. Increased supplies may be expected from the Dutch East Indies, Roumania, Peru, Alberta, Persia and Trinidad. Oil fuel is at present used as motor spirit, in place of coal for raising steam, and in Diesel and semi-Diesel engines. The increasing demand is most marked in the case of motor spirit, and methods of increasing the yield of petrol, of obtaining motor spirit from coal tar and from shale oil, and the use of alcohol in place of petrol are discussed. The consumption of petroleum for naval purposes is rapidly increasing, the oil being used for raising steam and for driving Diesel engines. All new warships for the United States Navy are designed for oil-fuel, and an area of about 100 square miles of oil-bearing land in California has been set aside as a reserve supply. Large quantities of oil-fuel are used on locomotives on the Russian State Railways, and the advantages are such that oil would be largely used in Great Britain if adequate supplies could be obtained at a moderate price. In view of the limited supplies, the principal development in the near future, apart from naval requirements, will be in the use of Diesel and semi-Diesel engines, since the high thermal efficiency of these engines makes it profitable to use oil-fuel at a price which would be prohibitive for steam raising. If the market value of oil-fuel becomes established on this basis, it will not be possible to use oil to any great extent in place of coal for raising steam.

Fluorspar in Glass. L. SPRINGER. (*Sprechsaal*, xlvii, 4, 21.)—The use of fluorspar in glass is not recommended except in special cases and under favorable circumstances. It attacks the hearth and walls of the furnace and makes the exit gases more injurious. By the formation and decomposition of silicon fluoride it produces a scum of silica on the surface of the glass, and alters the constitution of the glass in respect of the proportion of acid to base. On the other hand, it is said to impart brilliancy to bottle glass, and to increase its resistance under pressure.

Alloys of Cerium with Silicon and Bismuth. R. VOGEL. (*Z. Anorg. Chem.*, lxxxiv, 323.)—Much heat is evolved in the production of the alloys of cerium with both silicon and bismuth, and the reactive nature of the fused products has rendered thermal investigation difficult. Cerium and silicon form at least one compound, probably of the formula CeSi , and a eutectic containing 47 per cent. Si with a melting point of 1240°C . The alloys are hard and brittle, and stable in the air. At very high temperatures cerium, like magnesium, attacks silica and porcelain. Cerium forms with bismuth the compounds BiCe_3 , Bi_3Ce_4 , BiCe , and Bi_2Ce , the melting points of which, like those of cerium-aluminum compounds, are remarkably high, that of the compound, Bi_3Ce_4 , being approximately 1630°C . The bismuth alloys slowly swell up and disintegrate in air, moisture accelerating oxidation, especially with those containing 25 to 75 per cent. of bismuth, which may become heated to visible combustion; dilute acids attack the alloys readily. Hardness reaches a maximum with the compound Bi_3Ce_4 , for which it is between 5 and 6 on Mohs' scale.

Use of Pulverized Coal in Metallurgical Furnaces. J. LORD. (*Proc. Eng. Soc. of W. Pennsylvania*, xxix, 363.)—The coal (slack) used for puddling-, heating-, and other furnaces at the works of the American Iron and Steel Manufacturing Company, Lebanon, Pa., contains 1.1 per cent. of moisture, 33.2 of volatile matter, and 9.6 of ash. After drying, it is ground in horizontal (tube) or upright mills until 95 per cent. will pass through a sieve of 100 meshes per square inch (over 80 per cent. of the product will pass a sieve of 200 meshes per square inch) and conveyed through pipes to the storage tanks of the respective furnaces, to which it is subsequently delivered at a uniform rate, and under an air pressure of about one-sixteenth pound per square inch at the furnace mouth, by means of an adjustable "burner" of the screw-conveyer type; a low air-pressure is used to minimize the destructive effects of the projected fuel upon the interior of the furnace. The coal should contain at least 30 per cent. of volatile matter, and not more than 0.5 per cent. of moisture nor 1 per cent. of sulphur; the bulk of the ash is either deposited at the bases of the stacks or collected in the stacks by the aid of suction fans; the furnace charges are not adversely affected by the small amounts of ash which settle upon them. The average cost of preparing and delivering the fuel to the furnaces did not exceed 50 cents per ton of pulverized coal produced in 1912. In four furnaces employed for the production of high-grade puddled bar from gray forge pig iron, the maximum and minimum consumptions of pulverized coal per ton of puddled bar were, respectively, 1472 and 1169 lbs. over a period of two months; during the same period, the maximum and minimum amounts of fuel required for heating iron for rolling were 570 and 516 lbs., respectively, per gross ton of rolled bars. W. A. Evans stated that danger arising

from explosion or the spontaneous combustion of dry, powdered coal could be avoided by keeping the material in motion and not allowing it to remain in the storage-bins for longer than a week. Owing to the volume of flame produced, furnaces for pulverized coal require about four times as much combustion space as ordinary grate furnaces, and they should be entirely free from metallic cooling surfaces. Ash trouble may be minimized by the use of high-grade coal, by employing a bed of cinders in the combustion chamber, and by regulating the temperature of the flues to prevent deposition of slag. The use of powdered coal is stated to be more economical than that of producer gas or oil to the extent of about 25 per cent. in the former and probably much more in the latter case.

Incandescence Mantles, Rare Earths, and their Radio-active By-products. E. STERN. (*Z. Angew. Chem.*, xxvi, 806.)—Incandescence mantles are composed of 97 to 99 per cent. of thorium oxide, 0.8 to 2.8 of cerium oxide and a few tenths of a per cent. of beryllium and aluminum oxides. The higher proportion of ceria is used for mantles for high-pressure gas burners. The traces of the other oxides mentioned impart strength by producing a partial sintering of the deposit. The mechanical distribution of the deposit, or surface development, is determined by the textile thread used. Cotton, with short but fine fibres, gives a very porous but weak mantle, also liable to distortions due to sintering; ramie is much longer and coarser and gives a strong mantle with sufficiently developed surface more stable in the flame; the continuous filament of artificial silk imparts great elasticity, and its coarseness gives stability of form without impairing the luminosity. The ash content of the textile yarn must be very low—not more than 0.02 to 0.03 per cent. Three hundred tons of thorium nitrate are consumed per annum in the mantle industry, which represents about 3300 tons of monazite sand. The by-products include over 1000 tons of cerium oxide, three tons only of which are required for mantle making. A ton of sand, costing \$150, contains 2.5 mgrms. of radio-active mesothorium, of which 2 mgrms. (worth \$150) are recoverable. Thus 6 grms. of mesothorium are available as a by-product, but much larger quantities will probably be required for therapeutic purposes. Since the mantle industry cannot absorb more thorium, the extraction of larger quantities of mesothorium depends on the profitable utilization of the cerium. Of the 1000 tons of cerium oxide now obtained, 200 tons are employed in the manufacture of sparking alloys for cigar lighters, etc. The cerium is obtained by electrolysis of the fused chloride. 300 tons more are used in the form of the fluoride for impregnating arc-light carbons. A considerable outlet for cerium compounds might be found in the weighting of silk. The dyeing and photographic industries take small quantities of cerium salts. In commercial mesothorium, 25 per cent. of the radio-activity is due to radium which cannot be separated. Weight

for weight, mesothorium is 300 times more active than radium, but it breaks down in a much shorter time. One of its most useful products is thorium-X which is 200,000 times more active than radium and can be obtained in the form of solutions of any desired strength. The γ -rays of mesothorium are distinguished by a very high penetrating power.

Surface Devitrification of Glasses. C. J. BROCKBANK. (*Trans. Amer. Ceram. Soc.*, xv, 600.)—The physical and chemical changes which may occur in the surface layers of glass on reheating from the solid to the plastic state are due to the volatilization of the alkalis and the consequent production of silicates of a higher silica content. If maintained at the critical temperature for several days, the change will proceed throughout the solid glass. As the soda-lime silicates are the most liable to this defect, they were investigated with regard to the influence of their chemical composition on devitrification. The softening point was determined by the distorted reflection of a pointed steel rod poised vertically on the heated glass, and the dimming point was indicated by the disappearance of these reflections, while the muffle was provided with a thermo-couple. The results show that magnesia, and alumina to an even greater degree, are beneficial constituents of glass. It is a decided advantage to use dolomite. Alumina, in addition to its influence against devitrification, in amounts above three per cent. greatly increases the viscosity of glass.

A 30,000-Kilowatt Turbine. ANON. (*Sci. Amer.*, cix, No. 22, 407.)—The Interborough Rapid Transit Company of New York City has recently placed an order with the Westinghouse Machine Company for a horizontal turbine of 30,000 kilowatts capacity. The feature of this particular unit is its division into two turbine elements; the high-pressure element being a single-flow turbine, operating at 1,500 revolutions per minute, and the low-pressure element being a double-flow turbine, operating at 750 revolutions per minute. The machine is of the reaction type throughout, and comparatively low blade speeds are involved.

Production of a Pink Vitrified Floor Tile. R. HEIDINGSFELD. (*Trans. Amer. Ceram. Soc.*, xv, 140.)—The tile body was vitrified at cone 11, and the best pink was obtained from a mixture of Fe_2O_3 , 1, Al_2O_3 , 90, and Cr_2O_3 , 9 per cent. mixed as a stain with ten times its weight of the body-mixing: 64 per cent. of spar, 5 of flint, and 31 of kaolin. The pink thus obtained could be darkened to ruby by substituting 5 per cent. of calcium phosphate for 5 per cent. of alumina in the stain composition. This probably acted as a flux, producing at cone 11 a dark pink, which would have been produced without its use at a higher temperature.

Laminated Gears. ANON. (*Eng.*, xcvi, No. 2502, 790.)—A new method of making accurate gears is being developed commercially by Laminated Gears, Ltd., of Sheffield, Eng. The method is due to Mr. A. E. Terry and consists in constructing a spur-wheel or pinion by assembling together a number of discs of thin steel, in which teeth are formed by a stamping process. These stamping processes have been brought to a high pitch of perfection and it is claimed that very accurate gears can be rapidly and cheaply produced, while the use of thin plates facilitates the operation of case-hardening the teeth when it is desired. In assembling the discs, any errors of form can be distributed if need be, and successive discs are stepped forward by half the pitch. This gear runs very smoothly and silently. The makers claim that with these gears the noise is so reduced as to make them suitable for adoption where raw-hide pinions are now considered essential.

Gloves for X-ray Work. ANON. (*Sci. Amer.*, cix, No. 24, 451.)—The protecting gloves generally used for X-ray work are ordinary gloves having laid on the back a layer of rubber containing lead, as lead is known to stop the rays. But this layer is somewhat stiff and lacks suppleness; moreover, only the back of the hand is protected, and the palm and sides which are often exposed to the rays have no shield to protect them from their action. A French inventor makes use of a fabric which is much more flexible, and protects the whole of the hand from the rays. This fabric is woven from silk which is heavily "sized" with a lead composition, so that it contains three times its weight of lead. This tissue has the advantage of being far more elastic than that previously used, and acts as a very good screen for the X-rays, especially when the back portion is reinforced. It will doubtless be very serviceable to operators, who always run the risk of severe burns.

Talc as a Body Material for Pottery. C. W. PARMELEE and G. H. BALDWIN. (*Trans. Amer. Ceram. Soc.*, xv, 532.)—Commercial talc may be either talc or steatite. Considerable quantities can be substituted for clay in bodies without affecting the working properties. Even in small quantities it has a decided influence in promoting translucency and whiteness of ware. Talc promotes vitrification, which proceeds slowly and without the sudden fusion caused by lime; it also increases the toughness of the body, as measured, by loss on abrasion.

Economy of the Dry Blast. J. VON EHRENWERTH. (*Iron and Steel Inst.*, May, 1913.)—Calculations showed that the percentage economy of fuel due to the reduction of the moisture of the blast from 15 to 5 grammes per kilo, without considering the consequent reduction of temperature of the waste gases, varied between 6 and 11; and that due to the lowering of temperature of the waste gases

between 3 and 15. The total economy was from 9 to 25 per cent. The economy of drying the blast is greater the lower the temperature of the blast and the higher the original temperature of the waste gases. As there is less fuel charged, the total volume of material, and hence the volume of blast, per unit of production is less; thus the blowing engine and stoves can cope with a larger production, and the furnace yield is increased. The temperature in the melting zone is raised, and not only is the melting accelerated but the silicon is increased and the sulphur lowered. The advantages are, however, dependent on local conditions being greatest in the case of furnaces working with high temperatures both of blast and waste-gas, as in the production of ferromanganese, ferrosilicon, or ferrochrome, and in localities where the atmosphere is moist.

The International Congress of Consulting Engineers.—The Second International Congress of Consulting Engineers will be held in Bern, Switzerland, July 15 to 22, 1914. The conferences will be held in conjunction with the Swiss National Exhibition. The preliminary announcement gives a list of the organization committee and rules governing membership. Efforts will be made to hold the Third International Congress at San Francisco in 1915, from September 20 to 25, and it will form a part of the International Congress of Engineers which has been arranged for that date.



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THE PRESENT STATUS OF AIR-SHIPS IN EUROPE.*

BY

JEROME C. HUNSAKER,

Assistant Naval Constructor, U. S. Navy; Instructor in Aëronautics, Massachusetts
Institute of Technology.

I. GENERAL.

DURING the past three years aëronautics has developed from the field of invention into that of engineering. Air-craft are no longer invented out of pure speculation, but are designed according to engineering principles from the formulæ of the research laboratory and the data of the testing laboratory. A type is only new in the matter of the application of well-known principles, and is in the nature of an improvement and perfection of existing types. The requirements of military and naval authorities and the conditions of prize contests have created a demand for an engineer to design air-craft to meet given specifications. There has thus evolved a new technician, the aëronautical engineer. The air-craft of 1913 are principally to be distinguished by the evidence of engineering skill in their design and construction.

Recognition by the public of the value of air-craft in national defence has led to the development of an industry devoted to the supply of dirigibles and aëroplanes. Especially in France and Germany has aëronautics been stimulated in this manner. France developed the first practical dirigibles, but has until recently con-

* Communicated by the author.

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centrated her energy chiefly upon *aëroplanes*, with the result that at the present time the French army is estimated to have between 500 and 1000 *aëroplanes* in service. These *aëroplanes* are, moreover, of types that represent the highest development in *aëroplane* design. On the other hand, Germany, realizing the menace of this *aërial* force and the impossibility of duplicating it, has recognized the possibilities of the dirigible and given liberal support to the development of the ships of Count Zeppelin and Major von Parseval. Great sums have been spent and many lives have been lost, but the reward has already come. The German army now possesses a splendid fleet of 25 air-ships, representing the highest development in air-ship design. At the same time, France has brought her fleet of air-ships up to 18, and Germany has some 200 military *aëroplanes* with a large civilian reserve. It has become a race for the supremacy of the air between two great powers whose capitals lie within the radius of action of air-craft from each other.

England has recently joined the race for supremacy, and, apparently realizing that it is too late to overtake her continental rivals by the mere multiplying of units, has directed every effort toward the development of air-craft superior in design to the existing types. Foreign machines have been purchased liberally, and an *aërodynamic* laboratory and an experimental air-craft factory have been built. England's future in *aëronautics* is placed in the hands of an Advisory Committee headed by Lord Rayleigh and composed of distinguished scientists and engineers. The race then is not only between the factories but also between the laboratories. The production of a type of marked superiority will immediately make obsolete the *aërial* forces of other powers.

This rivalry between the great military powers is a most fortunate thing for the art, for in no other way could such intense interest in its problems be created. In laboratories, shipyards, and factories able men are working to improve the safety and reliability of *aërial* transportation with a devotion and intelligence that must lead to substantial advance in the general utility of air-craft.

II. DIRIGIBLES.

Dirigible balloons are self-propelled air-ships in which the lifting force is given by a gas-filled envelope beneath which cars are suspended for the accommodation of the power plant and passengers. In the rigid type the envelope is held in shape by a

rigid frame. In the non-rigid type the envelope is held in shape by internal gas pressure. A third type, the semi-rigid, seeks to provide a rigid frame only about the lower part of the envelope. The relative merits of these types can best be discussed after considering their qualities more in detail.

French Dirigibles.

The non-rigid dirigible was developed in France, between 1885 and 1900, by Renard, Krebs, Juillot, and Santos-Dumont, and has followed closely the improvement of the gasoline motor. At the present time ships of the non-rigid type are being built by the Astra Society (M. Surcouf), Zodiac, Clement Bayard, Lebaudy, and Godart. One wood-framed rigid Speiss dirigible is building at the Zodiac works.

Astra Dirigible (Fig. 1).

The Astra Society, of which the engineer E. Surcouf is director, has recently purchased the Torr s patents and is building ships of remarkable speed and elegance of design.

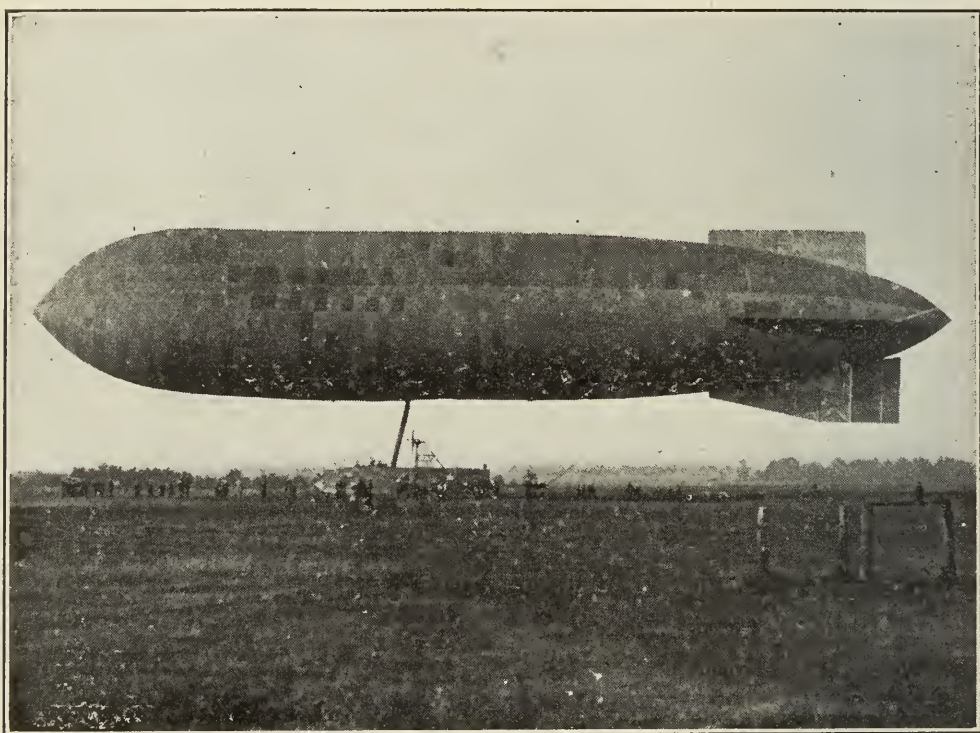
Envelope.—The envelope built on the Torr s system consists of three lobes in which the indentations or cusps run longitudinally. It has the appearance in general of a cucumber or an elongated cantaloupe. The internal gas pressure fills out the lobes, which have their cusps tied together by internal rope rigging. The ropes are, therefore, always in tension. Longitudinally, heavy ropes run from bow to stern along the inside of the cusps. The result is a long girder all of whose parts are in tension. The longitudinal strength so given the envelope makes it possible to moor such a ship to a post in the open by means of a cable from the nose. There is, of course, the extra weight of internal rigging over the envelope of ordinary fish-shaped form, and the lobed cross-section presents more surface per given volume than a circular section. However, the heavy belly-band and external rigging between car and envelope are avoided in the Astra-Torr s type and considerable head resistance saved. Furthermore, the total weight of the car comes upon the internal rope rigging and does not tend to strain the envelope. The envelope can then be made of lighter material than in the ordinary type. There is an additional advantage claimed from the fact that in any envelope subject to internal pressure the stress in the fabric varies as the radius of curvature at any point. The radius of

curvature is less in a lobed cross-section than in a circular one for a given total area of section.

Suspension.—The car is suspended below the envelope by vertical steel cables. The use of external rigging and crow's feet is entirely avoided, as the weight is taken directly by the interior rope girder and thence distributed to the envelope.

Car.—The car can be made very short without causing the back of the envelope to sag. The weight is evenly distributed by the internal roping. The car is covered with fabric or sheet metal.

FIG. 1.



Astra-Torrés non-rigid dirigible.

Its framing is an elastic structure of steel tubing easily taken apart for shipment or stowage aboard ship.

Motors.—Water-cooled motors of various commercial types have been employed. Usually two units are installed for the sake of reliability. In view of the elastic nature of the car, it is not considered necessary by the builders to mount the motors on springs.

Propellers.—Either or both motors may drive either or both propellers through proper clutches, reverse clutches, and gearing. Two wooden propellers are carried on brackets of steel tubing projecting upward and outward from the car. The propeller axis

is raised so that the centre of thrust may come nearer the centre of head resistance, and so that when the car is on the ground the whirling blades are no menace to the heads of bystanders.

Gas Pressure.—Hydrogen gas 15 mm. above atmospheric pressure fills the envelope. It may be noted here that hydrogen is now used in all air-ships. A lifting force of 1.12 kg. per cubic metre of gas 99 per cent. pure may be counted on.

Swivelling Axis.—The propeller axes are mounted in such a manner that they may be movable in a vertical plane parallel to the centre line of the ship. This is of assistance near the ground and in manœuvring.

Stability.—Static stability is given as in all air-ships by having the centre of gravity below the centre of buoyancy. The usual methods of naval architecture may be applied to the calculation of stability. Stability of route is given by the envelope form fitted with a vertical fin aft. The centre of side resistance is thus placed abaft the centre of gravity. The ship is steered by horizontal and vertical rudders on the after part of the envelope. Equilibrium in altitude is adjusted by the use of water ballast and a relief gas valve. The practice in free ballooning is followed. In descending from a high altitude, gas must be allowed to escape in order to reduce the lift. As the ship descends the gas pressure of 15 mm. is kept constant by inflating internal air-sacs or ballonets. The ballonets are connected by a duct of fabric to a blower in the car operated by the motors, or by hand in an emergency.

The following particulars of the naval type Astra-Torrés purchased by the British Admiralty are given as illustrative:

TYPE, ASTRA-TORRÉS XIV, SCOUT.

Volume in cubic metres	7500
Speed, kilometres per hour	82.2
Length, metres	75
Height, metres	21
Diameter, metres	14
Useful lift, kilos	2500
Crew	5
Radius of action in hours	12
Ballast, kilos	315
Cars	1
Propellers	2
Power, horsepower	400

This ship made a speed 51.1 miles per hour on her acceptance test, the world's record for dirigibles.

The company has under construction two ships of 24,000 metres cube in which it is expected 12 men may be carried 20 hours at over 80 kilometres per hour. Four 250-horsepower motors will drive four propellers.

Zodiac Dirigible.—The Zodiac Company builds non-rigid dirigibles in which the envelope is a solid of revolution below which the car is suspended. A heavy canvas belly-band is sewed to the bottom of the envelope. From toggles in this band hemp crow's feet lead to wire rope rigging attached to the car. In order to distribute the load uniformly to the envelope, the car is made long and narrow.

The horizontal rudder for control of elevation is mounted on the forward part of the car. In this position the rudder throws no force on the flexible tail of the envelope and also gives considerable lift by its aëroplane effect. The ship can thus be caused to ascend without loss of ballast.

The following details are given of their latest ship:

TYPE, FLEURUS AMÉLIORÉ.

Volume, cubic metres	14,000
Speed, kilometres per hour	79
Length, metres	100
Diameters, metres	16
Crew	12
Radius of action, hours	20
Cars	1 of length 26 m.
Propellers	3
Motors	3 Zodiacs.
Power, horsepower	675
Altitude, metres	1,800

In case of a forced landing without assistance an anchor with 150 metres of line can be thrown out to hold the ship head to wind.

Two machine guns are mounted on the car and one on a platform on the top of the envelope, reached by a ladder running through a trunk in the envelope.

Clement Bayard (Fig. 2).

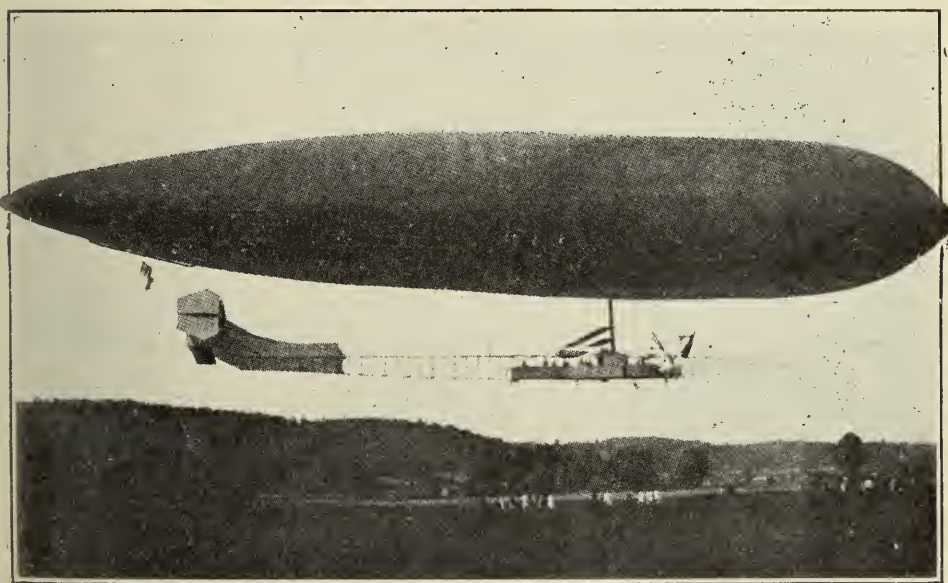
Dirigibles built by this firm have the benefit of the resources of one of the greatest automobile plants in France. Their situa-

tion industrially is interesting, and well worth considering by American firms contemplating air-craft manufacture. In the Clement Bayard factory, when air-ship building is slack, the skilled and experienced mechanics are absorbed in other departments of the works as machinists, erectors, upholsterers, etc.

The principal features of Clement Bayard ships are:

(1) Variable pitch propellers for reversing or changing speed. It is considered that the propellers can be worked at high efficiency, both at full and half power, by properly adjusting the pitch.

FIG. 2.



Clement Bayard non-rigid dirigible.

(2) A vertical lifting propeller of variable reversing pitch absorbs some 50 horsepower from a shaft geared to the main motors. This propeller is used in getting away from the ground, or to check downward velocity in landing. It is in many ways a simple substitute for swivelling propeller axes.

(3) An *aéroplane* surface over the centre of gravity of the car can be moved in inclination by the pilot. The lift of this plane assists in climbing.

The French army possesses three large Clement Bayard airships, besides the "Adjutant Vincenot" and "Deputy de Lôme."

The following details are given of a scout type supplied to the French army.

TYPE, SCOUT.

Volume, cubic metres	6,500
Speed, kilometres per hour	60
Length, metres	73.5
Diameter, metres	12.2
Fabric	Double diagonal, rubberized.
Radius, hours	15
Cars	1, length 10 m., width 1.8 m.
Propellers	{ 2 variable pitch for propulsion. 1 variable pitch for ascension.
Motors	
Power, horsepower	2 Clement Bayard on springs.
Altitude, metres	180
Ballonet volume, metres cube	2,000
Blowers	2,400
Blowers	2
Self-starter on motors. Sand ballast.	

German Dirigibles.

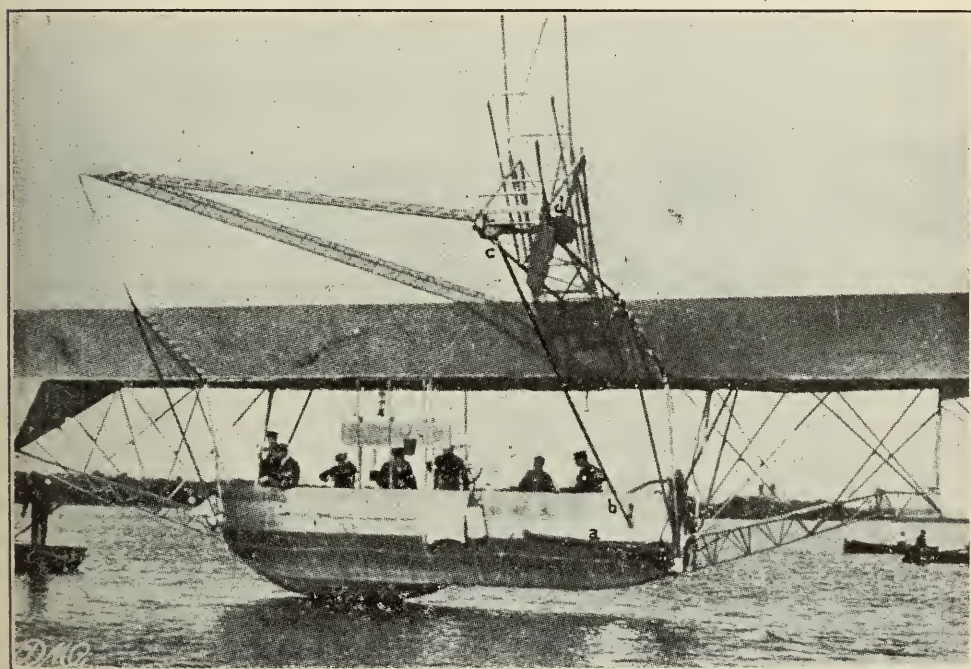
Zeppelin Rigid Dirigibles (Figs. 3, 4, 5, 6).—In Germany the development of air-ships has been greatly encouraged by the attitude of the army. The Zeppelin Company, manufacturing the rigid type Zeppelin dirigible at Friedrichshafen, as well as the Delag company operating passenger Zeppelins, have been heavily subsidized. In return for such financial support these companies are pledged to secrecy as to the construction of the ships.

It is likely, however, that the construction is in no way mysterious and is based on sound engineering practice and a great deal of experience gained from long and costly experiment, great failures, and appalling accidents. The essential feature is an aluminum alloy for the frame which is both light and tough. Naturally the composition of this alloy is kept secret.

The hull of the Zeppelin ships consists of a long frame of aluminum alloy bars and steel wires made up of longitudinal members tied together at intervals by some 18 to 20 wheel-like transverse partitions. In each of the sections so formed a gas bag of gold-beater's-skin is enclosed. The whole is enclosed in a linen waterproof non-gastight cover stretched over the frames. Each gas bag is fitted with a relief valve, spring loaded, or oper-

ated from the pilot's stand in the forward car. Gold-beater's-skin is found to be more impervious to hydrogen than any other material used to date. It is, however, low in tensile strength and can only be used to advantage on the dirigible air-ship when the gas is only slightly above atmospheric pressure. In the non-rigid ships the form is preserved by the inner pressure and rubberized fabric must be used. The hydrogen leakage in such case is about one per cent. in 24 hours under the best conditions, and is frequently greater.

FIG. 3.



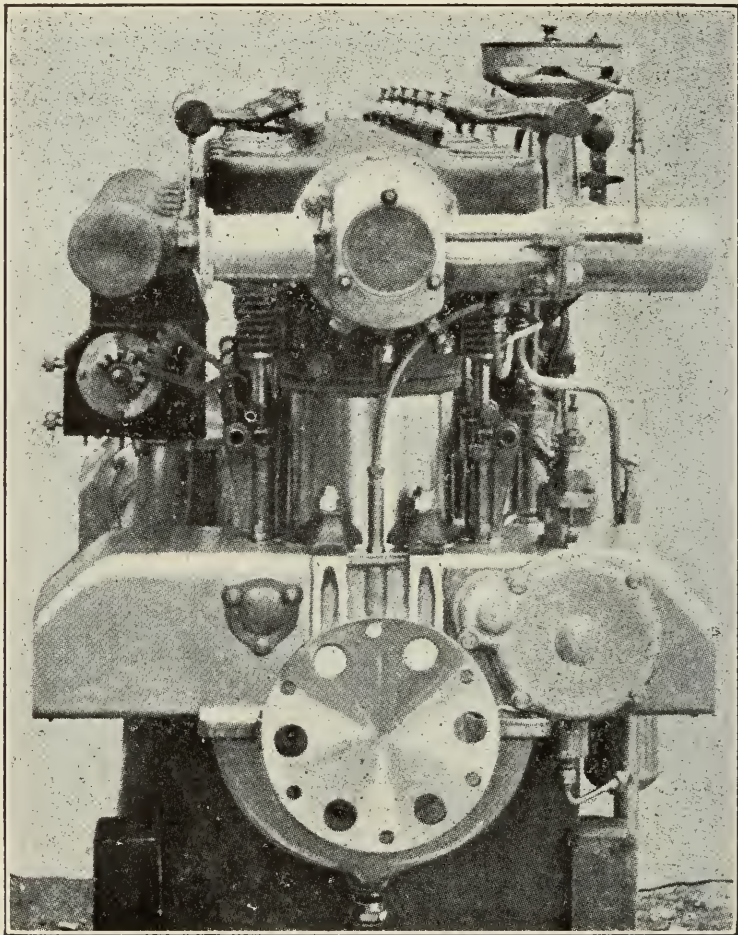
Forward gondola of Zeppelin.

Cars or gondolas are secured beneath the hull of the Zeppelin dirigible forward and aft. These cars are rigidly attached to the overhead framing and are very close to the envelope to diminish head resistance. There is also a middle car for the accommodation of passengers, armament, or freight. The power plant is carried in the forward and after cars.

The *motors*, three or four in number, are of special design for reliability and smooth running. All Zeppelins are now equipped with Maybach motors made by a subsidiary company. These motors have recently been put on the market and are used by the

Parseval air-ships. They are made in 200- and 300-horsepower units, 6 cylinders, water-cooled, double Bosch low-tension ignition, forced lubrication; 1100 to 1300 revolutions per minute; material special alloy steels; gasoline consumption .228 kilogramme per horsepower hour, oil consumption, .015 kilogramme per horsepower hour; weight of 200-horsepower motor,

FIG. 5.

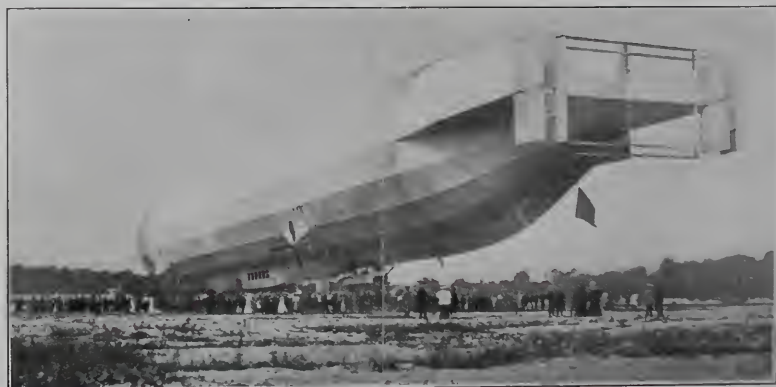
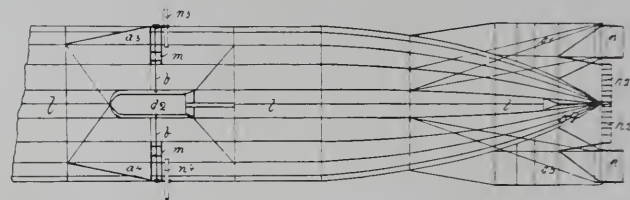
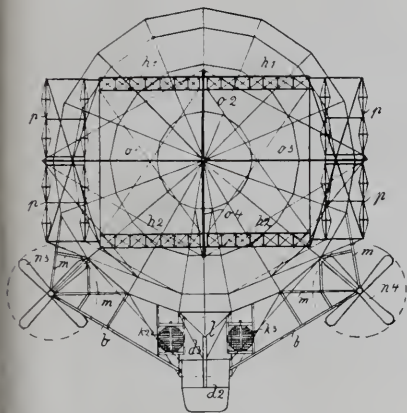
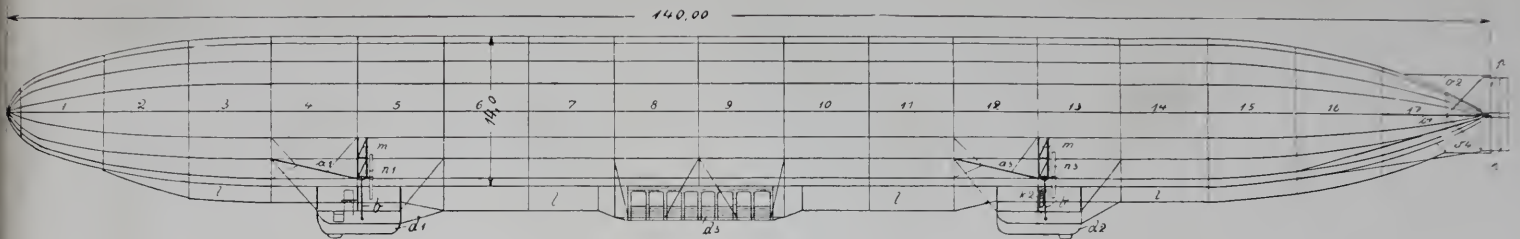


Maybach motor.

with cooling and ignition systems, 425 kilogrammes. These motors, on account of their even running, need not be mounted on springs. They operate well at reduced power, but usually when it is desired to reduce power one motor is stopped and the other worked full power.

Control.—The ship is steered by horizontal and vertical rud-

FIG. 4.



Plans and photographs of the passenger Zeppelin "Schwaben."

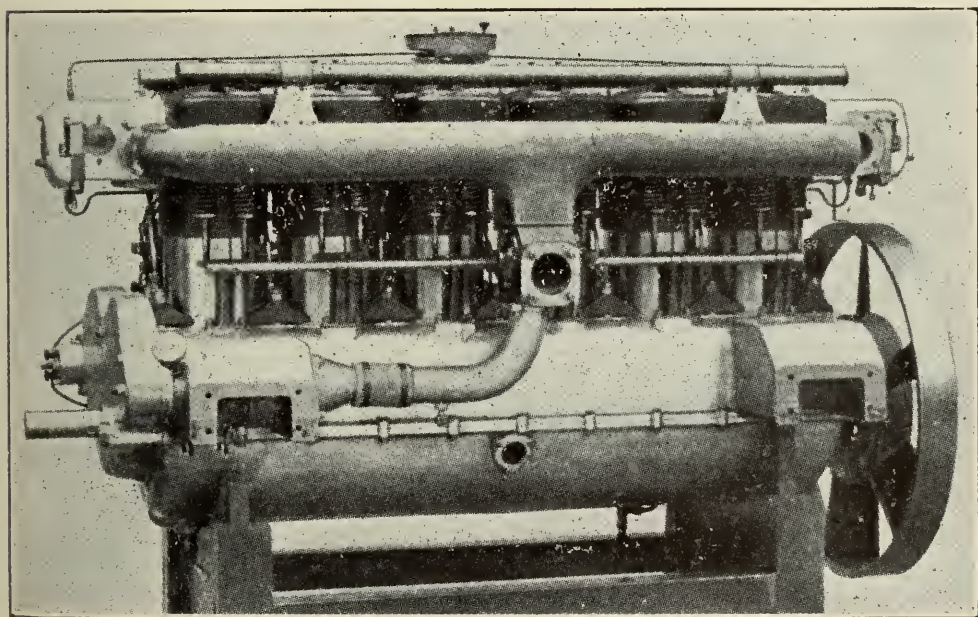
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ders attached to the rear of the hull and operated from the forward gondola. The ship can operate with a slight negative buoyancy due to the dynamic lift of the air upon the under side of the envelope when driven at full power in an inclined position. To balance with engines stopped, ballast and gas valves must be handled as in other air-ships. As the ship ascends gas is automatically released from each gas bag. The pilot can open 8 gas valves at once if he wishes to descend. Stability of route is given by a proper arrangement of fins on the rear of the hull. Water ballast is carried in tanks near each of the three cars. It can be

FIG. 6.



Maybach motor.

discharged from the pilot station by manipulating the valves. Before a landing, the motors are stopped, and if, when way is lost, it is observed that the head is heavy, the pilot opens the valve of the forward tank and discharges water until the ship comes to an even keel.

Propellers.—The propellers are mounted on side brackets. The two forward propellers are two-bladed and run at one-half the speed of the two after propellers, which are four-bladed. By use of clutches any propeller can be reversed or stopped regardless of the others.

The following details of the naval Zeppelin L1, lost in a gale over the North Sea, September, 1913, were published after the accident and are considered trustworthy.

Volume	22,000 cubic metres.
Length	160 metres.
Diameter	15 metres.
Speed	85 kilometres per hour.
Gas bags	18 gold-beater's-skin.
Radius of action.....	55 hours (at reduced power).
Power, horsepower	500 in three Maybach units.
Weight	27,000 kilogrammes total.
Net lift	7,500 kilogrammes.
Fuel and oil	3,000 kilogrammes.
Crew	17

The crew was made up as follows :

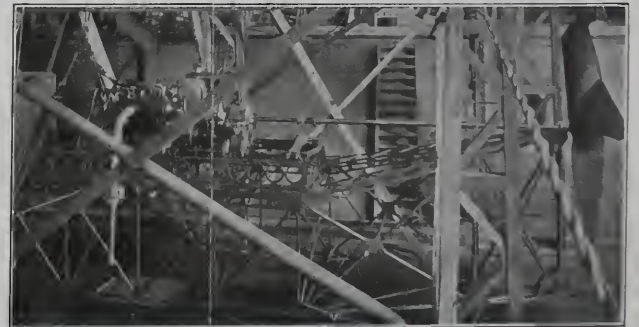
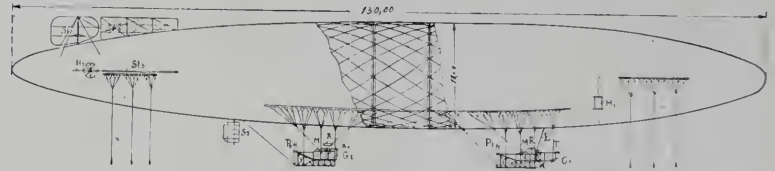
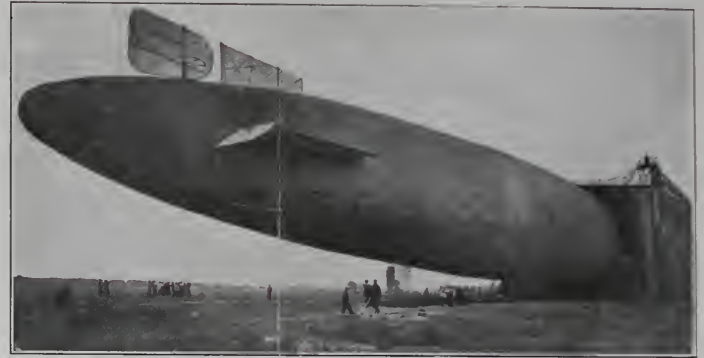
- 1 naval officer commanding.
- 1 engineer officer, chief engineer.
- 1 quartermaster, vertical rudder.
- 1 quartermaster, horizontal rudder and valves.
- 2 quartermasters, relief for above.
- 1 radio operator.
- 1 relief for above.
- 3 machinists.
- 3 relief machinists.
- 3 extra men, passengers and gunners.

The second naval Zeppelin L 2 represented the latest development of the type, and before she met with an accident on her acceptance trial was reported to have attained a speed of 60 miles per hour with 900 horsepower. The volume was 27,000 cubic metres, and radius of action estimated at 70 hours at reduced power.

Schütte Lanz (Fig. 7).—The rigid Schütte Lanz air-ship differs from the Zeppelin in having its frame made of wood. It is hoped that this construction will be lighter and tougher than metal and that the ship will not be so easily injured by contact with the ground as are the Zeppelins. The details of construction are not made public.

Parseval Dirigible (Figs. 8 and 9).—The non-rigid German air-ship is represented by the Parseval. In 1906 the Luft Fahrzeng Gesellschaft was formed to take over the patents of Major Professor Dr. A. von Parseval and to construct and

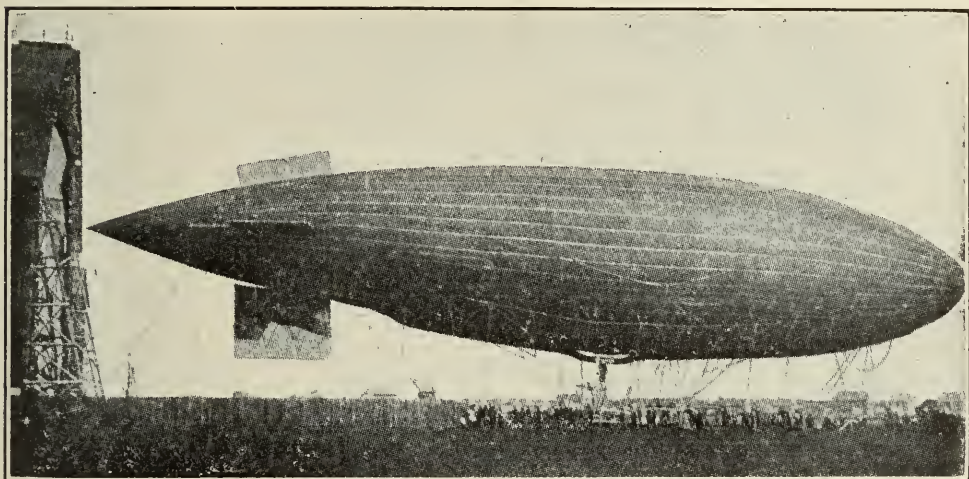
FIG. 7.



Schütte Lantz wood framed rigid dirigible.

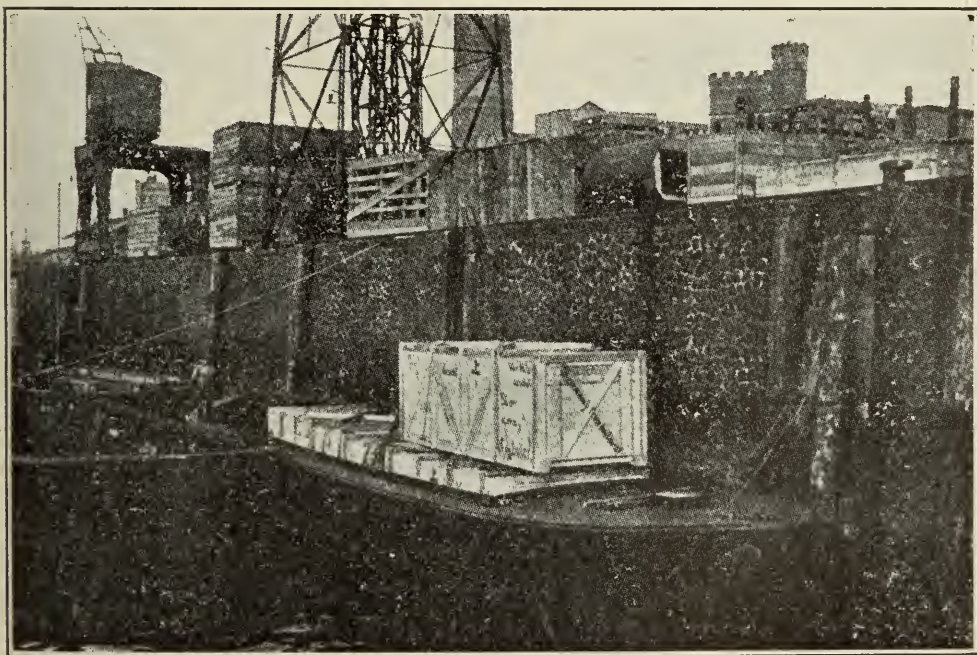
develop non-rigid air-ships. A research laboratory was endowed at the University of Göttingen and practical experiments under-

FIG. 8.



Parseval non-rigid dirigible.

FIG. 9.



Parseval dirigible of Fig. 8 boxed for shipment to Japan.

taken at the works in Bitterfeld. To date 20 ships have been built, and there have been no serious accidents. One ship was destroyed in its shed by fire due to carelessness.

The principal characteristic of the Parseval ship is that it has had its design based on engineering tests. The torpedo-shaped form of the envelope is the result of tests at Göttingen to obtain a shape giving the least head resistance for a given volume. The arrangement of fins and rudders for stability of route and control was also studied by the use of small models in the Göttingen wind tunnel. The strength of envelope fabric required is determined from the known pressure distribution about the hull in motion, as found by wind-tunnel tests at Göttingen, together with the known physical properties of the fabric as given by the testing machine.

The calculation of the bending moment in the envelope and the suspension of the car may be of interest. Only the general procedure can be given here. The method is described in detail by Haas and Dietzins in "Stoffdehnung und Formänderung der Hülle von Prall Luftschiffen," published by J. Springer, Berlin.

Strength Calculation for Dirigible (Non-rigid).

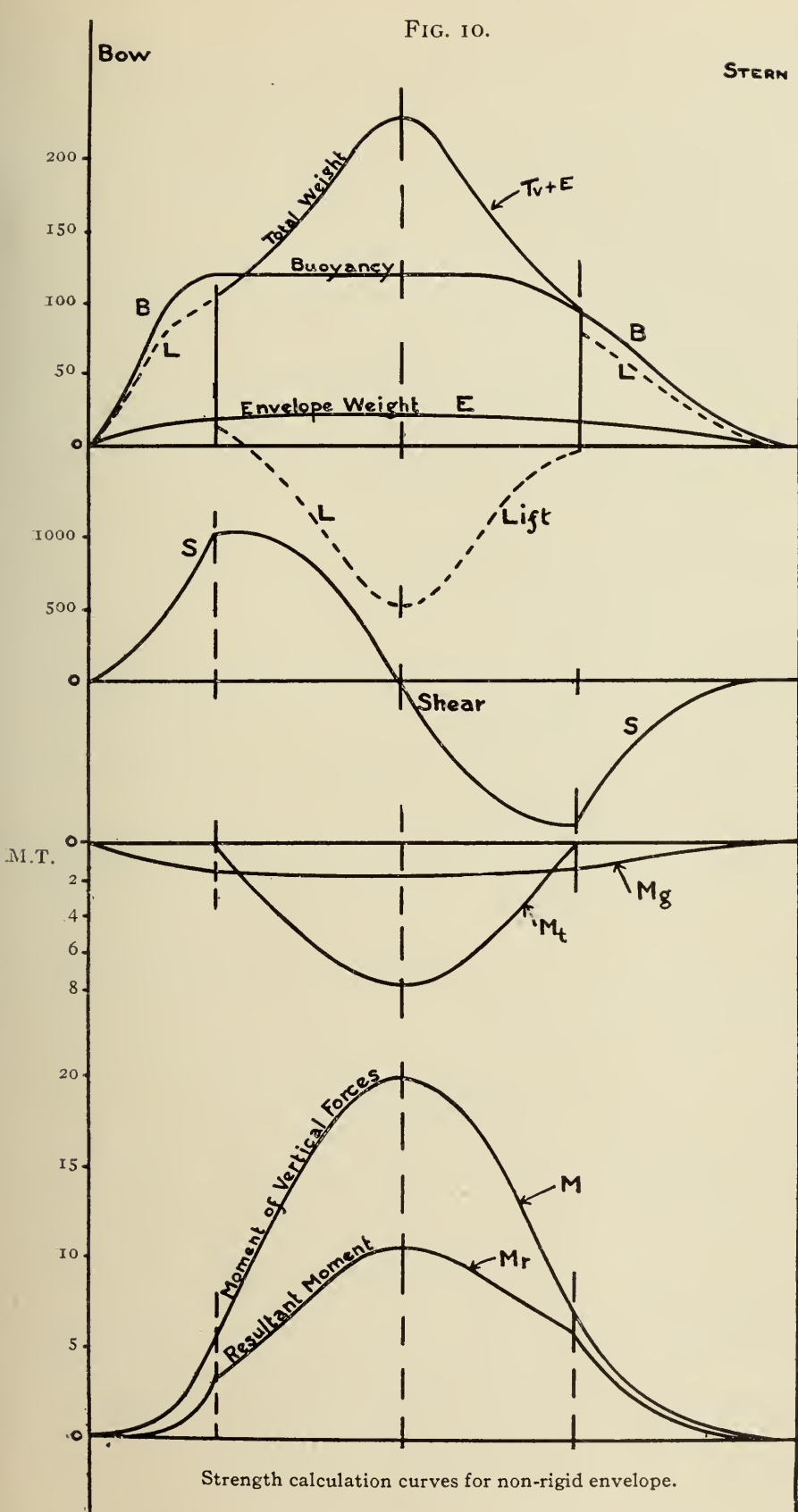
Buoyancy Curve.—Erect a curve representing the buoyant force of the envelope. Such a curve has ordinates proportional to the cross-sectional area at each point along the length of the envelope. This curve is shown in Fig. 10 as B .

Envelope Weight.—Erect a curve E representing the weight of the envelope with all attachments, such as fins and rudders.

Car Weight Curve.—The car is suspended from the belly-band attached to the envelope by a system of rigging, and its weight is distributed among the individual ropes in a manner that can be estimated for any given inclination of the fore and aft axis of the ship. Suppose, in Fig. 11, the ropes each have a different tension T . There is then a horizontal component T_h and a vertical component T_v for each such rope of the suspension. Estimate the value of T_v for each rope and construct a curve superposed above the curve of envelope weight. The resultant represents total weight, $E + T_v$.

Load Curve.—The difference between the total weight curve and the total buoyancy curve is the load curve L , whose total area is zero, but which lies both above and below the axis.

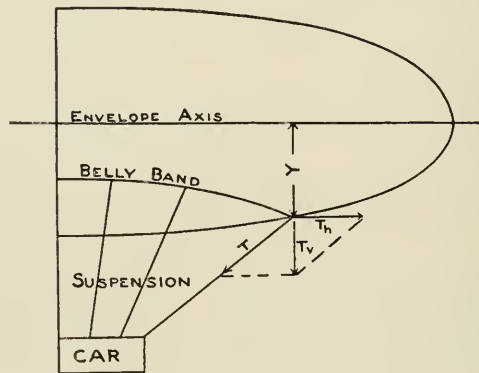
Shear Curve.—The integral of the load curve L , by a well-known principle in applied mechanics, represents the shearing force at any section. Such a curve is drawn at S .



Bending Moment Curve.—The integral of the shearing force curve is the curve of bending moments M . The nature of this bending moment is to cause the ends to be raised, and we represent it as a positive bending moment. This is the moment due to the vertical forces. In addition to this moment, we must superpose the moments due to horizontal forces.

Gas Pressure Moment Curve.—Over a cross-section of the envelope the pressure difference at the top is greater than that at the bottom, due to the difference in weight of a column of gas and an equivalent column of air of the same height. If the pressure difference at the level of the axis of the envelope is p_0 , the pressure difference at a distance y above the axis is $kyp_0 + p_0$, or an excess of kyp_0 . The moment about the centre of such a force on

FIG. 11.



an element dA of the cross-section is $dM = kyp_0 dA \cdot y$, and integrated over the cross-section.

$$M_g = \int k p_0 y^2 dA.$$

In the case of a circular cross-section, this integral reduces to the form $M_g = KR^4$, where R is the radius. We may now calculate the value of M_g , the moment due to gas pressure for each section of the envelope, and plot the curve M_g of Fig. 10.

Moment of Horizontal Components.—We have seen that the force T in each element of the suspension has a horizontal component T_h . The moment of this force about the centre of the envelope is yT_h , where y is the vertical distance of the point of attachment of the rope below the centre line of the envelope. By

calculating yT_h for each rope of the suspension, we can plot the curve M_t representing the bending moment due to the horizontal forces acting in the suspension.

The moments due to the above and to difference in gas pressure tend to lower the ends of the envelope, and, according to convention, are negative moments and should be laid off below the axis of the plot.

The difference between the ordinates of a curve representing $M_g + M_t$ and the curve of moments M gives a curve of resultant moments M_r . This curve represents the actual bending moment in the envelope at every point. It is important to adjust the design so that this curve shall be as nearly uniform as possible. A large hump in the middle of it represents a high bending moment at the midship section.

The midship section is stressed by the internal gas pressure p according to the well-known boiler formula :

$$f_g = \frac{\pi r^2 p}{2\pi r} = \frac{rp}{2}, \text{ where}$$

f_g = pounds tension per foot circumference.

r = radius in feet.

p = pressure above atmospheric in pounds per square foot.

The tension on the bottom of the envelope due to the bending moment M_r is represented by :

$$f_m = \frac{M_r R}{I}, \text{ where}$$

R = radius of section in feet.

$I = \pi R^3$ the moment of inertia of the circumference.

M_r = resultant moment at midship section in pounds-feet.

f_m = stress in envelope in pounds per foot run at top and bottom of section.

The total stress in the envelope at the bottom of the midship section is a tension.

$$t = f_g + f_m$$

At the top of the envelope at the midship section the force f_m is a compression. The resultant tension is here :

$$t = f_g - f_m$$

FIG.

Parseval

Type.	(Projected) Military air- ship.	(Projected) Passenger air- ship.	Military air- ship.	Passenger air- ship.
Volume.	22,000 cb.m.	22,000 cb.m.	16,000 cb.m.	16,000 cb.m.
Length.	160 m.	160 m.	137 m.	137 m.
Height.	24 m.	24 m.	24 m.	23.5 m.
Diameter of envelope, max.	16.5 m.	16.5 m.	15.5 m.	15.5 m.
Motors.	4 of 180-200 H. P.	4 of 180-200 H. P.	4 of 180-200 H. P.	3 of 180-200 H. P.
Propellers.	2 pair four- bladed	2 pair four- bladed	2 four-bladed	2 four-bladed
Bulkheads.	2	2	1	1
Cars.	2	2 and 1 cabin	1	1
Maximum speed in metres second:				
(a) with 4 motors.	23	23	22-23	.....
(b) with 3 motors.	20-21	20-21	20	21
(c) with 2 motors.	17-18	17-18	17-18	18
(d) with 1 motor. ....	.....	.....	.....	.....
Useful lift.	8000 kg. for 15° C. and 760 mm. ba- rometer	7700 kg. for 15° C. and 760 mm. ba- rometer	6300 kg. for 15° C. and 760 mm. ba- rometer	7200 kg. for 15° C. and 760 mm. ba- rometer
Radius hours:				
(a) with 4 motors.	26.5	20	20	.....
(b) with 3 motors.	35	27	27	20
(c) with 2 motors.	53	40	40	30
(d) with 1 motor. ....	.....	.....	.....	.....
Radius kilometres (tank fuel only):				
(a) with 4 motors.	2200 km.	1650 km.	1650 km.	.....
(b) with 3 motors.	2600 km.	2000 km.	2000 km.	1500 km.
(c) with 2 motors.	3300 km.	2500 km.	2500 km.	2000 km.
(d) with 1 motor. ....	.....	.....	.....	.....
Maximum altitude.	2500 m.	2500 m.	3000 m.	3000 m.
Distribution of useful lift:				
Crew.	1200 kg. (15)	640 kg. (8)	720 kg. (9)	640 kg. (8)
Fuel.	3600 kg.	3600 kg.	3600 kg.	2700 kg.
Radio and cabinet.	250 kg.	250 kg.	250 kg.	250 kg.
Armament.	500 kg.	.....	500 kg.	.....
Equipment, searchlight, etc.	140 kg.	200 kg.	140 kg.	140 kg.
Ballast and passengers.	2310 kg.	3000 kg.	1100 kg.	3470 kg.

12.

Air-ships.

Military air-ship.	Military air-ship.	Military air-ship.	Military air-ship.	Military air-ship.	Altitude ship.
15,000 cb.m.	10,000 cb.m.	9,300 cb.m.	7,400 cb.m.	2,400 cb.m.	10,500 cb.m.
125 m.	ca. 95 m.	95 m.	86 m.	53 m.	90 m.
24 m.	23 m.	23 m.	22 m.	15 m.	26 m.
16 m.	15 m.	14.5 m.	13.5 m.	9.5 m.	16 m.
4 of 180-200 H. P.	2 of 180-200 H. P.	3 of 180-200 H. P.	2 of 180 H. P.	1 of 120 H. P.	2 of 90 H. P.
2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed
I	.....	.....	.....	.....	.....
I	I	I	I	I	I
23	.....	.....	.....	.....	.....
20-21	.....	22.5	.....	.....	.....
17-18	19	18.5	21	.....	15
.....	.....	.....	.....	17	.....
5700 kg. for 15° C. and 760 mm. barometer	3000 kg. for 15° C. and 760 mm. barometer	3200 kg. for 15° C. and 760 mm. barometer	2550 kg. for 15° C. and 760 mm. barometer	800 kg. for 15° C. and 760 mm. barometer	3000 kg. for 15° C. and 760 mm. barometer
20	.....	.....	.....	.....	.....
27	.....	10	.....	.....	.....
40	15	13.5	10	.....	20
.....	.....	.....	.....	8	.....
1650 km.	.....	.....	.....	.....	.....
2000 km.	.....	810 km.	.....	.....	.....
2500 km.	1000 km.	900 km.	756 km.	.....	1100 km.
.....	.....	.....	.....	490 km.	.....
2500 m.	2000 m.	2000 m.	2000 m.	1100 m.	3800 m.
560 kg. (7)	560 kg. (7)	480 kg. (6)	400 kg. (5)	300 kg. (4)	560 kg. (7)
3600 kg.	1350 kg.	1350 kg.	900 kg.	300 kg.	900 kg.
250 kg.	250 kg.	250 kg.	250 kg.	.....	250 kg.
50 kg.	150 kg.	200 kg.	200 kg.	.....	50 kg.
200 kg.	.....	.....	.....	.....	150 kg.
1040 kg.	690 kg.	920 kg.	840 kg.	200 kg.	1090 kg.

In a non-rigid envelope the fabric is obviously unable to take a compressive force unless the internal gas pressure be sufficient to create a tension f_g superior to f_m .

The strength of the envelope is calculated from the most stressed portion, where $t = f_g + f_m$. The calculation is repeated for various inclinations of the axis of the envelope.

The following is a general description of the Parseval features (see Fig. 12) :

Envelope.—The envelope is made to the plans of the Parseval designers by the firm of A. Riedinger, Augsburg. This is one of the oldest balloon factories in the world, and has developed great skill in cutting and working rubberized fabrics. The material is purchased and tested at the Parseval works, whose specifications must be followed. Riedinger further tests it for gas tightness and stretching, in order to guarantee permanence of form. The fabric is cut in strips by the aid of paper patterns from which an empirical allowance for stretch has been deducted. The allowance for stretch is based on tests of samples and on experience with previous envelopes. Fabric of ultimate strength of one ton per linear metre is used for small envelopes, and fabric of strength two tons per metre for envelopes over 8000 cubic metres in volume. Over the propellers the fabric is doubled to protect the envelope from splinters in case of propeller rupture.

The nose is stiffened to stand the wind pressure at high speeds, and to permit mooring to a mast in the open.

Two ripping seams are provided. In case of a forced landing in a storm, the pilot can instantly deflate the envelope by pulling the rip cords. This feature is common to all non-rigid ships and is a great advantage of that type.

The internal gas pressure is from 20 to 30 millimetres of water.

The loss of gas through the fabric is about 1 per cent. of the total volume per 24 hours.

The envelope is fitted with a lower gas valve, spring loaded or opened at the will of the pilot. There is also an upper gas valve for use in case the lower one sticks. Normally only the lower valve is opened, as it releases the heavy and impure gas.

Ballonets.—Inside the envelope are two air-sacs or ballonets of total volume about one-third of the envelope. Air is admitted to one or the other ballonet by means of a three-way valve in the

trunk leading to the blower in the car. The size of the trunk and capacity of the blower are calculated to supply air to the ballonets at a sufficient rate to permit a given rate of descent without loss of form.

Suspension.—The car hangs from the envelope on six steel cables attached at the top to crow's feet of flax rope (electrical insulation of the envelope from the car) which toggle into a belly-band or fold of heavy canvas sewed to the bottom of the envelope. The load on the belly-band is then carried by belts of canvas passing over the top of the envelope. Each belt is enclosed in a pocket of fabric to prevent longitudinal motion, but is otherwise free to slip and adjust the load equally on the two sides of the car. Fore and aft motion of the car is prevented by fore and aft wire stays. Each of the two forward stays passes under rollers on the car and becomes an after stay. In the centre of the horizontal portion is fitted a rack held by a pinion. By turning this pinion the car can be hauled forward or aft through a distance of about 2 feet 6 inches. This displacement of the centre of gravity gives a powerful steering couple to be used when the ship has not speed enough to make the horizontal rudders effective. The longitudinal equilibrium may also be adjusted without discharging or shifting ballast.

Car.—The car is built of steel tubing in a substantial manner to withstand shock of landing. It can be taken apart for shipment. A sound-proof cabinet is fitted for the wireless telegraph operator. The framing of the car is completely enclosed by sheet metal or fabric. The pilot stands behind celluloid windows. In the ships under construction the car will be water-tight to serve as a float in landing on water.

Motors.—Two Maybach motors are mounted to operate in tandem on the same shaft. The car is made elastic to avoid use of springs, and to preserve shaft alignment several cardan joints are provided. An effective muffler and a jacking device for starting the motors are usually fitted.

Propellers.—Two steel plate propellers, four-bladed, with reversing pitch, or two walnut propellers, two-bladed, with reversing clutch, are mounted on side brackets and driven by gearing from one or both motors.

Wireless.—The radius of the Huth wireless set is about 300 kilometres. Total weight, 250 kilogrammes.

Searchlight.—A searchlight lighted by current from a dynamo driven by the motor shaft is good to distinguish large objects on a dark night from a height of 1000 feet.

Instruments.—Engine telegraph from pilot, barograph, barometer, manometer for each ballonnet, two manometers for gas, one aneroid pressure gauge for gas, one water gauge for cooling water, one oil gauge, one fuel gauge, one fire extinguisher, one surgeon's box.

Certain ships have also been fitted with a machine gun in the bow, and a bomb projector below the floor of the car.

Crew.—One chief pilot to maintain level, one pilot to maintain course, three machinists, one wireless operator, relief crew as required.

English Dirigibles.

English experience with air-ships was at first disastrous. The great rigid dirigible "Mayfly," built by Vickers, had a framework of aluminum alloy bars as in the Zeppelins, but the longitudinal strength was not sufficient and the ship's back was broken in the first attempt to launch her in 1911. The French Lebaudy air-ship "Morning Post," a semi-rigid, was lost the same year when she became entangled among telegraph wires and trees along a road near Farnborough. The cause of the accident was a wind slightly too great for the ship to manœuvre against.

From 1909 to 1913 the Royal Air-craft Factory built five small non-rigid air-ships of an experimental nature, ranging in volume from 600 to 6000 cubic metres. The last completed, the "Eta," of 6000 cubic metres, has made some very good flights. Its design is based on experience with the previous British air-ships and upon the purchased French and German dirigibles. In 1913 one Astra-Torrés 6500-metre ship and one Parseval 8800-metre ship were purchased. It is reported that these orders have been followed by further orders to these foreign factories. The great shipbuilding and armament firm of Vickers, Ltd., has secured the rights to build the Parseval air-ship in England, and Armstrong, Whitworth & Co. have secured the rights for an Italian ship, the "Forlanini." It is understood that three Forlanini semi-rigid dirigibles are to be acquired by the Admiralty. The

sudden expansion in dirigibles is due to the vigorous policy of the Admiralty in its desire to create an aërial fleet.

The following features of the "Eta," built by the Royal Aircraft Factory, may be of interest:

Envelope.—The envelope is made of "Continental" double diagonal rubberized fabric, treated with chrome yellow on the outside to protect the rubber from sunlight. Seams are gummed with rubber cement and stitched on a two-needle sewing machine by women especially skilled in this work. The form of the envelope is the result of tests in the wind tunnel at the National Physical Laboratory.

Suspension of the car is the ordinary French type by means of steel cables and crow's feet of flax toggled to a canvas belly-band.

Car is of steel tubing covered with fabric. No springs are fitted under the motors. The car is readily taken down for transport over seas.

Power plant consists of two 150-horsepower Salmson (French) motors driving through clutches and bevel gearing two four-bladed wooden propellers. Provision is made for swivelling the propeller axes in a vertical plane as in the latest Astra ships.

Crew is composed of one officer in charge, observer; one quartermaster to maintain altitude; one quartermaster to maintain course; three machinists.

For a landing, the assistance of about 40 men is required in windy weather, and provision is made for mooring by the nose to a mast in the centre of an open space.

Instruments.—One revolution counter, one barograph, one aneroid gas pressure gauge, two gas pressure manometers, two ballonet pressure manometers, one liquid compass.

Ballast.—In canvas water bags in car.

It should be stated here that the procedure of mooring to a mast was originated in England at the Royal Air-craft Factory.

Italian Dirigibles.

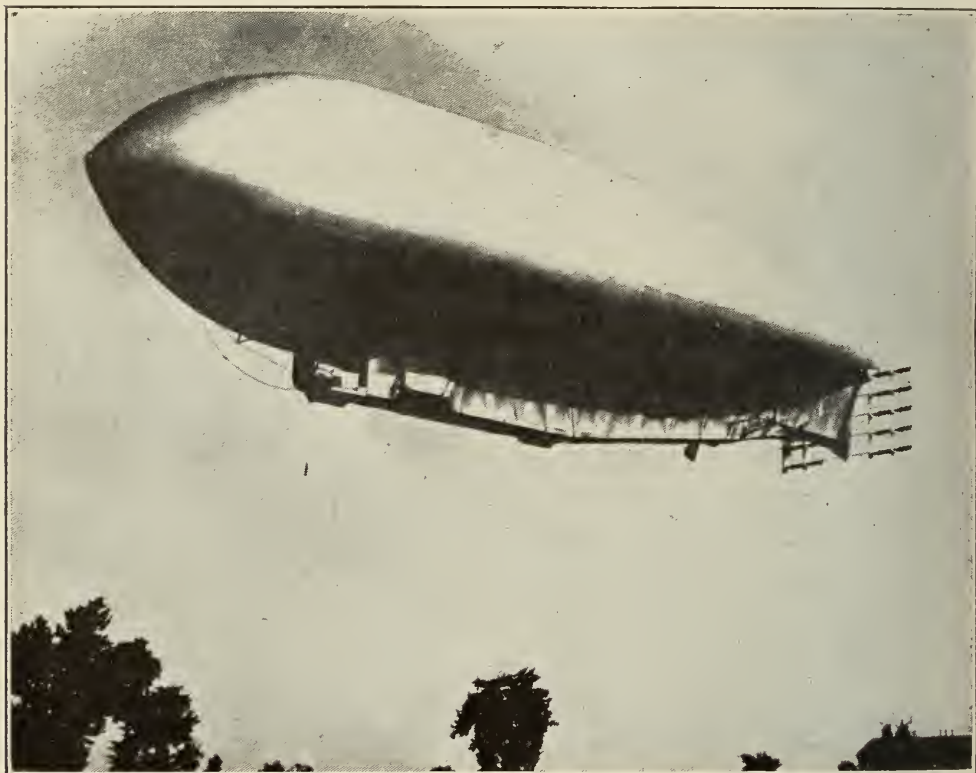
The Italian Government has three classes of dirigibles: the P class (small, of less than 5000 cubic metres), the M class (medium size, between 8000 and 12,000 cubic metres), and (under construction) the G class (20,000 cubic metres volume).

At the present time Italy has 5 P class and 5 M class, with 2 G class building.

The small P class ships have a speed of 50 kilometres per hour on a volume of 4500 metres, and are not considered suitable for war scouting. They are valuable for training purposes, however.

The M class is represented by five semi-rigid ships of 12,000 metres, designed by Captains Crocco and Ricaldoni. The keel is

FIG. 13.



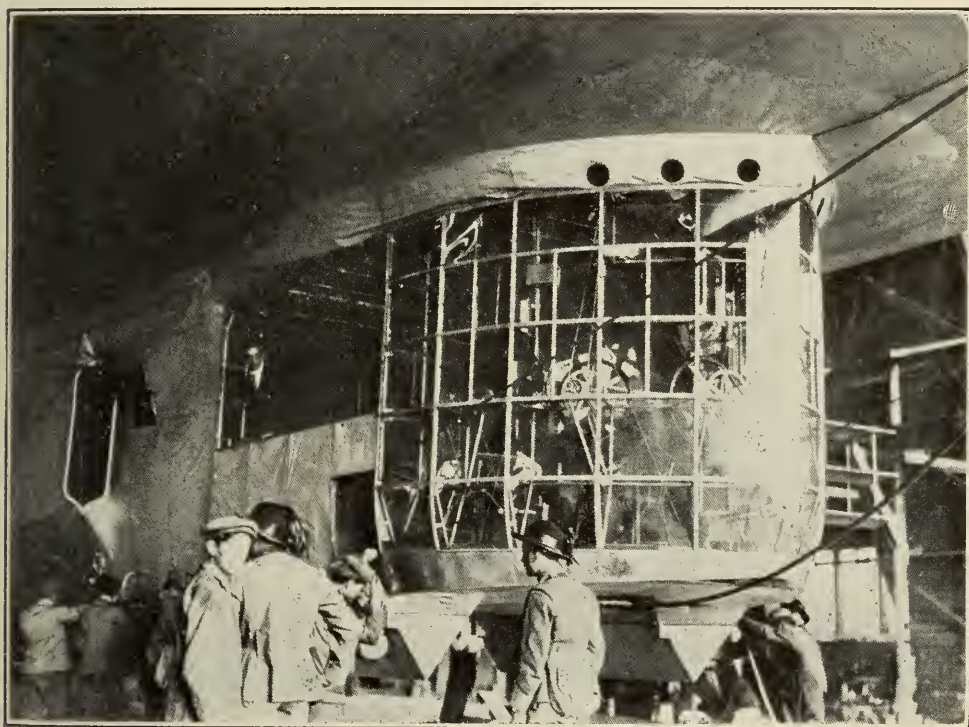
Forlanini semi-rigid "City of Milan."

a rigid structure built into the envelope. The car is a completely enclosed boat provided with windows. The crew are thus protected from the weather. A speed of 70 kilometres, or 44 miles per hour, is given by two 250-horsepower motors. Usually Italian motors are used: Fiat, Isotta, etc. Radius of action is 1000 kilometres, or a maximum flight of 35 hours at reduced power at an altitude of 1000 metres.

The "Forlanini" semi-rigid ships have recently been very successful. The Italian army has one ship of 12,000 metres,

and is reported to have under construction one GI or "Forlanini" of 20,000 cubic metres, speed 72 kilometres, 800 horsepower. A larger ship is projected of volume 24,000 cubic metres and speed 100 kilometres on 1000 horsepower. The British Admiralty is reported to have recently ordered three "Forlanini" ships, one to be built in England and two to be built in Italy.

FIG. 14.



Car of Forlanini "City of Milan."

The "Forlanini" type is distinguished by a completely enclosed car which forms part of a long rigid keel extending the entire length of the envelope. The keel is crescent-shaped longitudinally and square-sectioned transversely. The ends of the keel are tied together by a steel cable running through the envelope.

The envelope is in two parts, meeting along the top centre line. The inner envelope is made up of 14 compartments. The inner and outer envelopes are kept apart by ballonets. The British ships are reported to displace about 12,000 cubic metres, length 72 metres, diameter 8 metres, two three-blade propellers

of diameter 4.2 metres, maximum speed 44 miles per hour, on two Fraschini motors of 100 horsepower each.

By virtue of the semi-rigid construction the ordinary suspension of the car from the envelope is avoided and the car placed inside the keel. Head resistance is, of course, reduced, and the power required for a given speed still more reduced.

The Italian army has at present one German Parseval non-rigid air-ship of 10,000 cubic metres and another ordered.

DISCUSSION OF TYPES OF DIRIGIBLES.

The three types of dirigibles—rigid, semi-rigid, and non-rigid—in all probability will continue to be built, as each possesses peculiar advantages.

The rigid Zeppelin type is considered to possess the following advantages over the other types:

(1) Possibility of constructing of enormous size with correspondingly great speed, radius of action, and weight-carrying ability.

(2) Cellular subdivision of gas bags, giving less danger from ripping or bursting of envelope. In a rigid ship one gas bag may be pierced by a shot without loss of more than one-twentieth of the lift.

(3) Preservation of longitudinal strength independent of gas pressure.

(4) Reduction of head resistance due to suppression of external suspension to car.

(5) Ability to descend rapidly, due to (3).

(6) Ability to go for long periods of time without material loss of gas, due to the fact that gas bags may be made of gold-beater's-skin.

(7) Long life, because outer covering of envelope is not rubberized or gas-tight.

(8) Form does not change, due to stretch of fabric.

(9) Less severe temperature expansion of gas in passing from sunlight to shade. The outer envelope and dead air space insulate the internal gas bags.

(10) Gas pressure is only slightly above atmospheric when at low altitudes, and the flow of gas from a shot-hole in a Zeppelin has about one-half the velocity of flow from a similar hole in a non-rigid envelope at the same altitude. Also in the former case

the flow of gas ceases when the gas below the level of the hole has escaped.

On the other hand, the large rigid air-ships are very costly, and require still more expensive sheds to house them. On the ground they are very unwieldy and require two or three hundred men to hold them against a moderate breeze. There is great danger of straining the rigid frame in a bad landing—an injury that destroys the usefulness of the ship. The rigid ship cannot be transported by rail or steamer.

The disadvantages of the rigid type are the corresponding advantages of the non-rigid type. For example, the peculiar advantages of the non-rigid may be enumerated as follows:

(1) They are less costly for the same service.

(2) Due to saving of weight of rigid frame, a non-rigid ship may be designed to have the same lifting power as the rigid ship, but with a 20 per cent. smaller envelope volume.

(3) The housing is less costly, due to smaller size. At the same time, several ships with envelope deflated may be stowed in a single shed.

(4) The non-rigid ship is not injured so easily on the ground. Its longitudinal strength is given by gas pressure, and is not affected by a bad landing.

(5) The smaller non-rigid ships can be moored to a mast in the open.

(6) The non-rigid can instantly deflate its envelope, if it has to land in a strong wind, by pulling the ripping panel.

(7) About 50 men can hold a 10,000 cubic metre non-rigid in a moderate breeze.

(8) The non-rigid ships can be easily deflated, taken apart, and shipped in several packages by motor truck, railroad, or steamer. This is a great advantage for naval purposes.

(9) Injuries to the envelope of the non-rigid ship are easy to repair, and, though the envelope may last but three years, it can be replaced at a cost of less than \$2 per cubic metre.

Like all compromises, the semi-rigid dirigible, in an effort to combine some advantages, has combined some disadvantages of both the rigid and non-rigid systems. For example, the semi-rigid dirigible has advantages to some extent of the non-rigid type as enumerated above in paragraphs 1, 2, 3, 5, 6, 7, and 9, and advantages 1, 3, 4, 5, 8, enumerated for the rigid type. On

the other hand, the greatest advantage of the non-rigid type—its portability—it does not possess. The long keel is heavy, easily damaged, and cumbersome. It combines the vulnerability to puncture of the non-rigid ship with the unwieldiness of the rigid ship. Furthermore, the placing of the gasoline motors in a car built in the keel immediately below the envelope is a fire risk not to be ignored.¹

It is probable that difficulties of construction render the rigid type desirable for ships of more than 16,000 cubic metres volume. Below this size, the non-rigid type appears to have the advantage. The semi-rigid system has been most satisfactory when applied to ships of volume near 16,000 cubic metres.

Air-ships of any type are in the position of small boats on the sea. It is impossible to navigate in a storm. It is true that a powerful high-speed Zeppelin could make headway against a wind that a less powerful non-rigid ship could not cope with. This advantage is not, however, a practical one, for the apparent advantage of the great rigid ship exists only while in the air. The larger ships can neither leave their sheds nor enter them when a wind is blowing that does not present insuperable difficulties for the non-rigid ships. A wind of 15 miles per hour is about the upper limit for the safe handling of a Zeppelin on the ground, where this wind must be taken broadside on (across the mouth of the shed).

A form of rotating shed mounted on a turntable has been built in Germany and should be an advantage in case of unfavorable wind. The construction is very costly, however.

ACCIDENTS TO DIRIGIBLES.

Disputed points in general design and possible improvements to be desired are best considered in the light of the accidents that have occurred. Unfortunately, the development of a new kind of transportation is inevitably accompanied by many accidents, and very often our attention is drawn more forcibly to the accidents than to the successful trips. This statement applies to dirigibles, submarines, subways, great passenger steamers, and 18-

¹ The Italian semi-rigid Forlanini dirigible "Citta di Milano" was destroyed, April 9, 1914, on the ground, by explosion of hydrogen and subsequent fire. Fifty persons were injured. Cause unknown.

hour trains. Accidents are horrible enough in themselves, and are, furthermore, unnecessary and useless if some lesson is not taught.

Considering first the non-rigid air-ship, we find that in the first Santos-Dumont ship the envelope collapsed in descending, due to the fact that blower and ballonnet were not powerful enough to keep the gas pressure constant. The second Santos-Dumont non-rigid had its envelope collapse when it ascended in a rain storm, due to contraction of gas with cold. Here again the ballonnet was not powerful enough. The conclusion from these accidents is that a powerful blower and large ballonnet are absolutely essential to the safe operation of a non-rigid dirigible. However, in the cases cited the aëronaut was merely forced to descend abruptly. He was in no way injured.

In the Santos-Dumont 6 of 1902 the gas all ran to one end of the envelope, and lifted it up so that the controls could not bring the ship down to an even keel. There was danger of the suspension fouling the propeller and the bag bursting. This is a disadvantage of a large non-rigid ship. In the Santos-Dumont 7 silk non-gastight partitions proved a remedy. In the large non-rigid dirigibles projected for 1914, both in France and Germany, it is proposed to fit partitions in the envelope. There is danger of bursting in case a wave motion is set up, due to the impact of gas on the ends.

The Santos-Dumont 7 of 1902 was directionally unstable, due to its form of envelope. The same trouble has been had with other ships. The remedy lies in placing the centre of side resistance abaft the centre of gravity, as in the ordinary weather-cock or feathered arrow.

The "Republique," 1909, was destroyed when a propeller burst and cut the envelope. The cut quickly extended to a great tear, and the ship crashed to the ground. Ships since that day have employed a fabric that will not tear easily if punctured. Usually the fabric is made up of two or three layers of cloth, with intervening layers of rubber, the whole pressed together and vulcanized. The warp and weft of fabric in each layer are diagonal to the threads of the other layers. This is called diagonal doubling. Such fabric does not tear readily. An extra patch is placed on the envelope over the propellers to protect it from splinters.

A great many ships of all types have been lost by attempting to navigate in too high a wind. Examples are:

1901—Santos-Dumont 5, landed in a tree.

1902—Lebaudy, landed in a forest.

1907—Lebaudy, broke away from 200 men holding it and floated out to sea.

1909—Clement Bayard, broke away from 40 men holding it and blew into the Seine.

1911—"Morning Post," lost control and became entangled among telegraph wires and poles.

1913—Zeppelin L2, caught in cloudburst over North Sea and pounded into water, where the high sea broke her back.

The obvious conclusion from such experience is that an air-ship should have a speed sufficient to cope with the winds to be expected in her district. It is estimated that near Paris a ship capable of a speed of 45 miles per hour can manoeuvre 234 days in the year, allowing for 75 days of fog, snow, or rain.

The speed of 45 miles per hour is figured as 8 miles per hour greater than the wind. It is usually considered that for safe handling a dirigible's speed should be at least 8 miles per hour greater than that of the wind. A speed of 45 miles per hour in France is the minimum for general military utility. It is possible that in the southern part of the United States, and near Cuba and Panama, a ship of 45 miles per hour maximum speed could navigate over 300 days in the year. In any case, the speed of our ships must be based on probable meteorological conditions. There is no ship yet designed to navigate in a tempest. A speed between 50 and 60 miles per hour is, however, practicable.

At the present time, hydrogen lifting two and a half pounds per cubic metre is the only gas used for air-ships. Coal gas gives only about half this lift. Also, gasoline or similar volatile distillates is the only fuel used for internal combustion motors. Unfortunately, both gasoline and hydrogen form explosive mixtures with air, and the motor has an ignition system and a hot exhaust pipe and muffler. The combination is a bad fire risk, and many ships have been lost by fire. In the past year or two the installation of wireless telegraphy and its high potential sending current is another source of danger. The car is in the non-rigid ships electrically insulated from the envelope.

The following ships lost by fire give an indication of the importance of the fire risk in design:

1879—Wölfert's rigid ship, a gasoline fire in the car ignited the hydrogen in the envelope.

1908—Zeppelin 3: torn by wind from moorings and blown aloft, where it caught fire and exploded.

1912—Zeppelin 10: burned in its shed at Düsseldorf.

1911—Parseval 5: burned in its shed at Münden.

1913—Zeppelin L 2: fire in the forward car ignited hydrogen in the envelope, where it exploded with great violence. It is reported that in this new ship an effort at high speed was to be made by reducing head resistance in every way. The cars were placed close under the envelope, and a connecting passage from forward to after car built inside the envelope. Leakage of gas into this passage (*Laufgang*), which was not ventilated, probably found its way to the forward car. A wind shield here made an eddy or suction behind it in the car, and air and gas from the *Laufgang* could easily have been sucked in. A flooded carburetor, red-hot exhaust pipes, or other cause could then have ignited the gas. In any case, the ship was completely destroyed in the air by the force of the explosion.

It seems that the cars containing the gasoline, motors, guns, wireless sending station, and other sources of fire should be kept well away from the envelope. In the rigid and semi-rigid ships the cars are very close to the envelope. In the non-rigid ships difficulties of suspension require the car to be hung on cables some distance below the envelope. So far as fire is concerned, the non-rigid ships seem safer, though the low car causes an increase of head resistance. The relief valves on the envelope are often placed at the bottom so as to discharge the heavier and more impure gas. In the non-rigid ships this may not be a source of danger, as hydrogen rises as soon as released and should not reach the car. The placing of gas valves should, however, be very carefully considered with reference to the suspension of the car.

It has been suggested that certain explosions of balloons in which no fire was carried may be due to discharge of atmospheric electricity. Thus a balloon on touching the ground may be charged with static electricity of potential equal to that of the upper air. Unless this potential be lost in descending, it may easily be possible for an electrical discharge to take place between

a part of the balloon touching the ground and some metal part, such as a gas valve. Gas valves are largely made of fibre, in view of this danger, and in dirigibles all metal parts are electrically connected. The envelope of most non-rigid ships has no metal parts, and is insulated from the car by crow's feet of flax rope.

The great difficulty in design of the rigid type ships is to get sufficient stiffness with small weight.

The following accidents represent the loss of several fortunes:

1897—Schwartz rigid: back broke from jar in striking ground.

1900—Zeppelin I: frame bent on first trip.

1900—Zeppelin II: frame broken by pounding on ground when anchored in the open.

1900—Zeppelin III: frame broken when jammed in door of shed.

1901—Zeppelin VIII: frame broken when jammed in door of shed.

1911—Mayfly, Vickers: back broken when launched.

The rigid hull of such ships is a most delicate structure and renders the rigid air-ship most vulnerable when improperly handled. The importance of a highly-trained personnel is apparent.

Due to the fact that the rigid hull cannot be deflated, the rigid type ships are only useful where adequate housing facilities are provided. The reliability of the motor is a vital factor in all dirigible operation. The Zeppelin II in 1900 was forced to land in an open field by motor stoppage. The ship was anchored to stakes driven in the ground, but a wind came up and pounded the vessel against the ground until the frame was broken. A non-rigid ship would have deflated the envelope in such a case. In 1901 motor trouble forced the non-rigid Santos-Dumont 5 to land on a roof. No damage was done, however. In modern dirigibles considerable weight is sacrificed to reliability in the design of the power plant. The motors are water-cooled, of moderate piston speed, and of substantial construction. Duplicate ignition systems are provided, and forced lubrication. It is becoming the practice to enclose the motors completely in order to protect them from rain and snow. Self-starting devices are frequently fitted, but in any case hand cranking or jacking arrangements are installed. Gauges are fitted to give warning of a low supply of fuel, oil, or water.

For any air-ship there is a limit to the wind which she can be expected to cope with, and it is obviously of great interest to have a trustworthy weather forecast before undertaking a voyage of any duration. In Europe the greater part of the violent storms come from the Atlantic, and their approach cannot always be known. The loss of the naval Zeppelin L1 over the North Sea in 1913 was primarily due to a violent and sudden rain squall of whose coming the weather forecasts gave no warning. In 1910 the Zeppelin "Deutschland" was caught in a strong rising current of air and the pilot was unable to prevent her being carried to a great height. The gas was chilled and contracted at the high altitude, and probably the pilot had opened his valves to check the ascent. In any case, the ship suddenly lost her buoyancy and dropped into a forest.

It is thus clear that it is not alone necessary that for safe dirigible operation the surface winds be not violent. The pilot should have assurance that disturbances in general meteorological conditions are not approaching. It has been found that pilot or sounding balloons, sent up before a voyage in a dirigible is started, may give valuable warning of unsettled conditions in the upper atmosphere. The pilot should have reports from observation stations in the vicinity, as well as a weather map showing the general barometric pressure distribution. During a voyage the barometer must be watched and its indications given careful consideration. In ships fitted with wireless hourly reports may be received from the home station. Safety in dirigible operation, questions of design not considered, must always depend upon the judgment of a weather-wise pilot and upon the trustworthy meteorological data that are supplied him.

The above discussion of accidents has been undertaken here in order to emphasize the vital importance of:

(1) Sufficient blower power and ballonet volume for non-rigid ships.

(2) Partitions in long non-rigid envelopes to prevent shifting of gas.

(3) Sufficient fin area abaft the centre of gravity to give directional stability.

(4) Provision against envelope of a non-rigid ship ripping when punctured.

(5) Sufficient speed to cope with winds to be expected in the district.

- (6) Every possible precaution against fire.
- (7) Electrical connection of metal parts.
- (8) Adequate housing for rigid ships.
- (9) Reliable motors.
- (10) Correct weather forecasts.
- (11) Experienced personnel.

In nearly all the accidents cited there is some one cause that might be prevented in subsequent ships. In this way improvements in design and operation have been brought about that now make a dirigible a fairly safe and useful method of transportation. The press naturally describes an accident in great detail, but, now that successful aerial voyages are of such frequent occurrence, mention of such performances is only made when the breaking of a record or the presence of distinguished persons gives news value to the report. For example, the three Zeppelins—"Hansa," "Sachsen," and "Viktoria Luise"—during the past summer made passenger trips every fair day of from two to six hours' duration without a single accident. Long-distance trips were also made between various German cities, and one to Copenhagen.

COMMERCIAL USE OF DIRIGIBLES.

Due to high cost of maintenance, some danger, and dependence upon weather conditions, air-ships have not yet been proved of great commercial value. It is true that thousands of passengers have been carried by the Zeppelins of the Delag Company in Germany, but this company has been heavily subsidized in order that its operation should not show a loss. The entertainment of tourists is a legitimate commercial enterprise, but the air-ship cannot be considered of real service to commerce and industry until it can maintain regular schedules between fixed points that men's affairs require them to visit. The passenger-carrying business so far has been of the nature of sight-seeing trips up the Rhine or around and over Berlin. There is no more delightful way to see the country. Provided with a good map, a passenger can become acquainted with a great area of country in a few hours' time. This facility for observation leads at once to the consideration of the use of air-ships in time of war.

MILITARY USE OF DIRIGIBLES (Figs. 15, 16, 17, 18).

The dirigible operating in clear weather at an altitude of some 5000 feet is fairly safe from gun-fire and yet not too high for a trained observer to detect the movements of large forces on the ground, general features of fortifications, number and type of ships in a harbor, presence or absence of bridges and railroad tracks. The dirigible can stop its motors and float slowly above

FIG. 15.



Neuhausen from a height of 3000 feet.

ground it is desired to observe. The *aéroplane* cannot perform such service except by circling above a given area, thus reducing its fuel supply and future usefulness. The great test in military operations of the dirigible will be for long-distance reconnoissance. In a country whose probable enemies lie within the radius of action of air-craft, dirigibles may be used at or before the opening of hostilities to pass over the enemy's frontier to observe the mobilization of troops, their direction of march and probable destination. A dirigible, unlike an *aéroplane*, is fitted with wireless telegraph both for sending and receiving messages, and

may keep in constant communication with its base. The radius of action in a calm of large rigid air-ships may be 2000 miles, and medium-sized non-rigid ships 1000 miles. An aëroplane cannot be depended on for more than 400 miles when an observer must be carried in addition to the passenger. A dirigible can save fuel by drifting with the wind, and it is well known that by selecting a suitable elevation a favorable wind can very often be found when the wind on the ground is contrary.

FIG. 16.



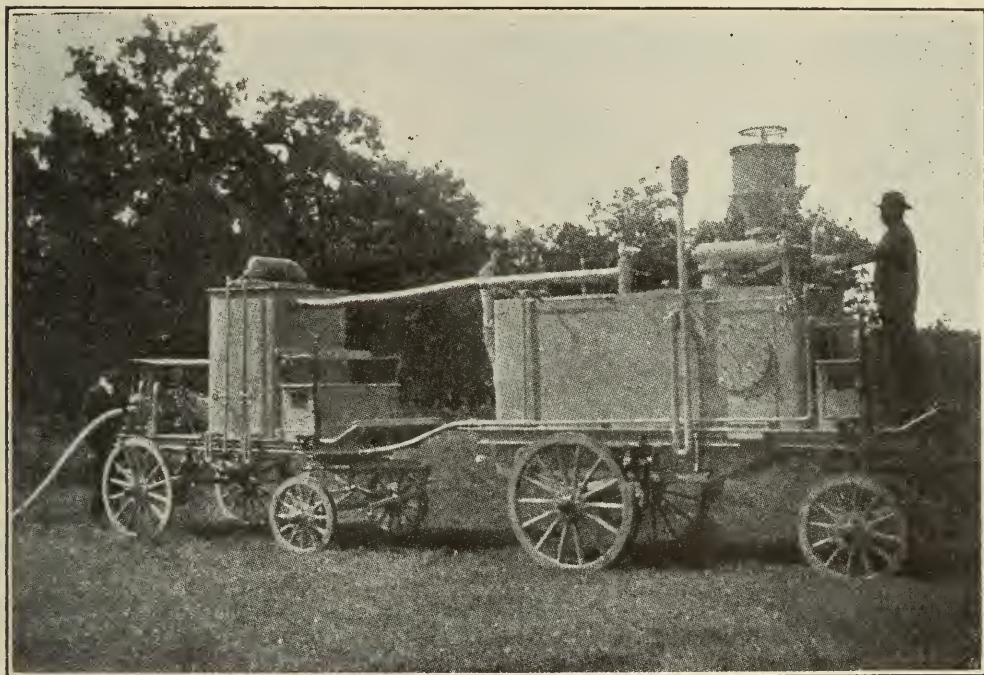
Neuhausen from a height of 3000 feet. Telephoto from dirigible.

The greatest usefulness of the dirigible will be at night. At the present time aëroplanes cannot be flown at night. The dirigible at night can travel close to the ground without danger from gun-fire, and can observe the extent and disposition of camps.

For pure reconnoissance work an army could use large rigid dirigibles for distant scouting to develop the enemy's principal movements preceding the actual meeting. Due to its portability, any expeditions into the interior of an enemy's country or in the colonies would be best served by non-rigid dirigibles. These ships are easily crated for shipment, and can be inflated in the field from bottled hydrogen or a portable gas plant drawn by

a motor truck. Large sheds are not necessary, as the ship can be moored in the open to a post in good weather and deflated in a violent storm. In cases where both rigid and non-rigid air-ships might be used, the non-rigid ships might observe from a safe altitude the progress of a battle and the effect of artillery fire. Aëroplanes would be used for transportation of staff officers, dispatch duty, and scouting within the limits of the battle-field. The same functions at night would be performed by the non-rigid dirigible.

FIG. 17.



Portable hydrogen generator.

In case of siege, where the enemy has possession of a great expanse of surrounding country, communication with the besieged forces could be had by means of a dirigible of sufficient radius of action. Its going and coming would be masked by darkness.

The use of dirigibles in modern wars will be greatly restricted by the enemy's aëroplanes, which must be supposed superior both in speed and climbing power. On the other hand, a dirigible will mount several machine guns and, having a steady gun platform, can deliver a much better directed fire than the aëroplane. It is

not clear what might be the result of an aerial skirmish between a scouting dirigible and the enemy's aëroplanes. However, a unit of a dirigible fleet is so much more valuable than a whole squadron of aëroplanes that it seems unlikely that a dirigible would seek an encounter. In the case of modern armies, where aëroplanes may be supposed numerous and their pilots ready to take risks, the operations of dirigibles will be, no doubt, chiefly conducted under cover of darkness or in strategic reconnoissance far removed from the field of battle.

FIG. 18.



Gun for firing at air-craft.

A large dirigible can carry over half a ton of bombs or torpedoes. In view of the great target which it presents, and the provisions made in European armies for the attack of dirigibles by shrapnel fire, it is unlikely that it will be attempted to drop bombs on an army in march or upon a fortified place. Furthermore, at night it may not be possible to drop bombs with any chance of hitting a given object. There will be cases, however, where a dirigible may be sent out to destroy a bridge, an enemy's dirigible shed, an arsenal, a canal lock, or other large object. The dirigible can make its journey by night, and before dawn, as soon as there is sufficient light, can descend close to its target.

drop half a dozen 100-pound gun-cotton torpedoes, and be away before she has been fired on. The surprise is no doubt to play an important part in any offensive operations of dirigibles.

The effect of bombs dropped from aloft in no way compares with that of shells from great guns on account of lack of penetration before explosion. The best that can be expected is a surface explosion and incendiary effect. The moral effect of dropping bombs into an enemy's camp at night must not be ignored. Doubtless, the damage may not be very great, but the effect of hourly explosions would certainly be depressing. A camp offers a large target, and a dirigible might easily hover above it all night above the range of searchlights. Its motors would be stopped or used at low power to hold position. Mufflers can be made as effective as in automobiles.

The rules of civilized warfare probably will not tolerate the dropping of bombs upon an enemy's city, and in case the place is besieged and non-combatants warned to leave it, bombardment by artillery will probably be more effective than dropping bombs from an air-ship during the night.

It seems to be the general opinion that the use of dirigibles will be more for reconnoissance than for offensive operations, but that in special cases offensive operations promise a chance of success.

NAVAL USE OF DIRIGIBLES.

The large rigid type dirigible may be of service to a navy whose probable adversaries have dock-yards and naval bases within the radius of action of such air-ships. The opening of hostilities might be preceded by a dirigible reconnoissance over the enemy's sea-coast to observe the disposition of his fleet. A dirigible might easily pass over all of the enemy's great dock-yards and naval bases and so ascertain whether the enemy's fleet be concentrated or scattered, the number of ships engaged in coaling, the number of ships in dry dock or otherwise out of action. It might well be that such reconnoissance would reveal such a condition of unpreparedness that, without formal declaration, war might be opened by an inferior force with a fair chance of destroying a division of the enemy's fleet before the other units could be mobilized.

For such strategic reconnoissance the great endurance and radius of action required indicate the rigid type ship as more suitable than the medium-sized non-rigid ship.

After war has been declared, if it be determined that the enemy is to take the offensive with one out of several probable objectives, it will be of vital importance for the defending navy (which we might assume inferior in force) to keep its fleet concentrated and endeavor to engage a portion of the enemy's superior fleet under advantageous conditions. The enemy's tactics might be to send a few ships to make a demonstration at several points and then to throw his main force upon another point which he might expect to find undefended by ships of the defending fleet. If all probable points of attack were patrolled by non-rigid dirigibles, it might be possible to determine the enemy's plan of attack and the number and power of the units in each of his subdivisions. The defending fleet could then select its conditions of battle and engage with a part of the enemy with a definite knowledge of his power and of the location of the other division of his fleet.

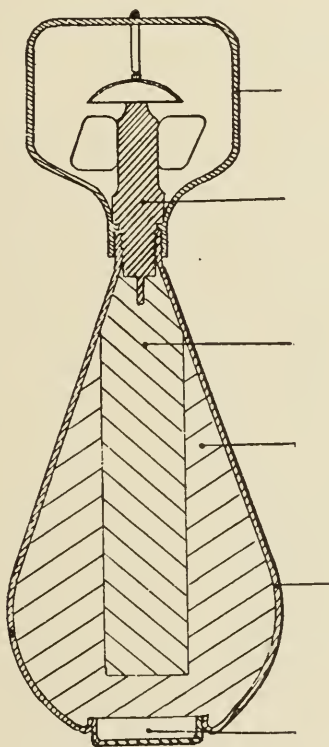
The number of dirigibles needed for a complete patrol of extensive coastal waters and islands would indicate the use of non-rigid ships whose radius of action is sufficient. This service could also be undertaken by hydro-aëroplanes, but, since the scout is waiting for the enemy to come within, say, 200 miles of a given point, the hydro-aëroplane could hardly afford to proceed to a point 150 miles out to sea, there to circle round until the enemy is sighted. The dirigible can float about with motors almost stopped for a day or more without great loss of fuel.

On the other hand, the enemy with the superior fleet might wish to know the location of the defending fleet in order to seek it out and destroy it or to blockade it in port. If the action were to take place at a great distance from the enemy's base, an advanced base near the field of operations would be seized, portable non-rigid air-ships set up and inflated, and sent out on definite scouting expeditions.

In general it may be considered that the offensive power of air-ships would have little effect upon armored decked battleships. Bombs and torpedoes (Fig. 19) will burst on the surface of such decks, turret roofs, etc., and do local damage, but probably

will not injure any vital parts. A ship is a small target to hit from the altitude of 5000 feet, which is required by day to be safe from gun-fire. At night an air-ship may pass low over a ship, but in war time no man-of-war will show lights, and, unless the moon be bright, the dirigible has small chance of finding the ship. It is stated by some pilots that when an air-ship is over a steam vessel a red glow is seen down the funnels. A bomb dropped down a funnel would certainly seriously damage the

FIG. 19.



Dirigible torpedo.

uptakes. It may well be considered prudent to fit gratings over the top of smoke-pipes on battleships.

As in the case of military operations, there may be special cases when a dirigible may be required to drop incendiary or high-explosive bombs on dock-yards, drydock caissons, vessels building, magazines, and workshops. Great damage might be done, but the battle fleet could not in this way be greatly reduced in power.

It seems that the principal function of the dirigible in naval

warfare is to supplement the work of scout cruisers, and that its offensive powers would rarely be called upon.

In attempting to pass through waters in which mines have been laid, a dirigible could possibly conduct counter mining operations. A dirigible can also give warning of the presence of submarines, and, if required, could rid a passage of these dangerous craft by launching bombs upon or near them. For this duty the dirigible may pass at a very low altitude, as she has little to fear from a submarine boat, unless the latter be running on the surface.

Dirigibles will not revolutionize naval warfare, but may play an important, if auxiliary, part in it.

FUTURE PROGRESS IN DIRIGIBLES.

Progress in dirigible design will probably continue to be directed along the lines of rigid, non-rigid, and semi-rigid types, each type being specialized for different functions.

It does not appear likely that any gas other than hydrogen will be used, but it is not clear that gasoline is the fuel best suited to dirigible motors. The adoption of a less dangerous fuel than gasoline will be a step in advance. Tanks may be kept under pressure of carbonic acid gas or other non-inflammable gas.

Improvement in radius of action may be expected from improvements in motors, both in power for a given weight and in economy of operation.

The rubberized fabric of dirigibles at best allows a leakage of gas of about $\frac{1}{2}$ per cent. to 1 per cent. per day. In a 500,000 cubic foot ship this is a serious matter, and in 10 days a loss of lift of 10 per cent. may result. Laboratory experiments show various oiled and varnished silks to be more gastight than rubberized fabrics, but such silks have not yet been made sufficiently strong and durable for practical use. Gold-beater's-skin is gastight, but very expensive and difficult to handle. It may be expected that the future will bring forth an improved fabric.

Since the safety of a dirigible and its general usefulness depend to a large extent on speed, it is certain that every effort will be made to increase speed. The present speed of 50 miles per hour, when increased to 60 miles per hour, will give us a vastly more serviceable air-ship.

At the present time a dirigible in thick fog, rain or snow is likely to become lost and unable to return to its station. The German Zeppelin which landed at Luneville, France, recently in a fog is a case in point. It was most embarrassing to the Germans to have the French authorities become familiar with details of this ship. Since then experiments have been made in Germany to guide dirigibles enveloped in fog by means of wireless signals sent from two points. The relative intensity of signals received from the two stations by the dirigible is proportional to the relative distances of the ship from those stations. The method is reported to have been of some assistance. We may look in future to a perfection of such methods of orientation.

The future will also doubtless bring a multiplication of air-ship stations, each lighted at night by distinguishing lights.

Automatic devices for regulating the ballonnet pressure are under consideration and will probably prove of some help to the pilot.

In short, we may expect progress to be made in speed, power, radius of action, safety, and reliability. It does not seem likely that it will be necessary to go to enormous sizes to accomplish this advance. Size in itself is a grave disadvantage.

Meteorology, though not a part of air-ship design, will lend valuable assistance in operation by a better knowledge of the atmosphere. A great deal of attention is being paid to the upper air currents, and it may reasonably be expected that the future meteorological forecasts will predict the conditions in the upper atmosphere with the precision of its present bulletins on conditions near the surface of the ground.

Improvement in the past five years has been very rapid, but there is yet hope that further improvement may be made and that in the near future the dirigible air-ship will be not only an engine of war but a valuable agent in the service of commerce and industry.

Much of the expected improvement in the general utility of air-ships may be expected to result from research in the aëronautical laboratories maintained by the governments of Germany, France, England, and Italy. The practical application of these results of laboratory research will be made by the young men who are being trained as aëronautical engineers in the engineering schools.

Large Cylinders for Locomotives. ANON. (*Sci. Amer.*, cx, No. 8, 155.)—The Test Department of the Pennsylvania Railroad has been experimenting with superheater locomotives. As a result it has been determined that when a locomotive is converted from saturated to superheated steam, its cylinders should be enlarged. It is found that to secure maximum economy, the cylinders should be enlarged to such an extent that the maximum indicated horsepower will be developed at a cut-off not exceeding 30 per cent.

Electric Lights at Low Cost. ANON. (*Sci. Amer.*, cx, No. 8, 155.)—While it is obvious that an electric lighting system is a most desirable feature in an automobile, the high prices at which most of such systems are offered to the public preclude their use by many owners. Realizing this, a well-known manufacturer of automobile specialties has just brought out a new electric lighting system of novel construction; the principal feature of which is that it can be easily installed and sells for only \$12. The system comprises a dash lamp, a tail light and a portable trouble lamp. The body of each lamp is made of hard rubber instead of metal and contains a powerful lens. The tail lamp has a red lens for the warning signal and a slot underneath, with a white light for illuminating the license plate.

Evaporative Efficiency of Oil. ANON. (*Amer. Mach.*, xl, No. 14, 592.)—The evaporative efficiency of oil, when thoroughly atomized in a well-designed burner, is considerably higher than that of coal. Results of trials show that 1 lb. of crude petroleum with a net calorific value of from 18,000 to 18,250 B. T. U., will evaporate from 14½ to 15 lbs. of water, from and at 212° F. This is approximately 50 per cent. more than the same weight of coal would evaporate.

Rescuing from Submarine Boats in European Navies. ANON. (*Sci. Amer.*, cx, No. 12, 245.)—The subject of saving the lives of the men on submarine boats, the mechanism of which has become deranged, has been attracting considerable interest throughout the world recently. The importance of this subject was shown by a recent disaster in the British Navy. Several European navies have installed apparatus on their submarine boats for renewing oxygen and absorbing the products of respiration of the men on the boat for a period of 72 hours, during which time it is usually possible to effect a rescue, which otherwise would be valueless, as the men would have suffocated. Another popular method is to place in the boat a number of little machines designed to shut off the respiratory organs of the wearer from the water, and permit him to breathe fresh air supplied by a special device, until he can rise to the surface of the water, after which the device may be discarded; the balance of the apparatus serving as an ordinary life preserver until rescue can be effected.

THE RADIATION OF THE SUN.*

BY

C. G. ABBOT, S.M.,

Director, Astrophysical Observatory, Smithsonian Institution.

It is really extraordinary how much has been found out about the sun, when it is considered that the sun lies at the immense distance of 93,000,000 miles. There are various methods of ascertaining the distance of the sun, resting upon extremely diverse foundations, so that the close accord of their results to within about one-tenth of one per cent. gives us great confidence in the accuracy of the mean value. The angular diameter of the sun is also known to a great accuracy, and from this and the distance one determines at once that the diameter of the sun is 865,000 miles. How great this is as compared with the diameter of the earth—7,918 miles! From a consideration of the motions of the earth and the moon, it is found that the mass of the sun is 332,800 times the mass of the earth. In accordance with this, the gravitation on the sun is enormous compared with that upon the earth, so that a body which weighs 100 pounds at the earth's surface would be pulled toward the centre of the sun from the sun's surface with a force of nearly one and a half tons.

In accordance with the measurements of the diameter and the mass of the sun, it follows that the average density of the material composing the sun is very much less than that composing the earth. In fact, it comes out that the sun's material is only 1.41 times the density of water, whereas the mean density of the material composing the earth is 5.5 times the density of water. Notwithstanding this remarkable fact, it has been shown by spectroscopic work that the heavy metallic elements, such as iron, nickel, zinc, tin, copper, and others, occur in the sun as well as in the earth. The explanation for the discrepancy of density between the two bodies lies probably in the very high tempera-

* Presented at the meeting of the Section of Physics and Chemistry held Thursday, January 8, 1914, and published by permission of the Secretary of the Smithsonian Institution.

Illustrations: Fig. 1 from *The Astrophysical Journal*, by permission of The University of Chicago Press. Figs. 2, 3, 4, 5, 6, 7, from Abbot's "The Sun," by permission of D. Appleton and Co.

ture of the sun, so that the elements found there are in the form of gases, whereas upon the earth they are in the form of solids. We shall return to this fact later.

As viewed through the telescope, the sun at first sight is a very disappointing object as compared with the moon. Nevertheless, there is much of interest to be seen there. In the accompanying figure we see a direct photograph of the sun as obtained by Slocum, of the Yerkes Observatory, on May 18, 1910. Several

FIG. 1.

N



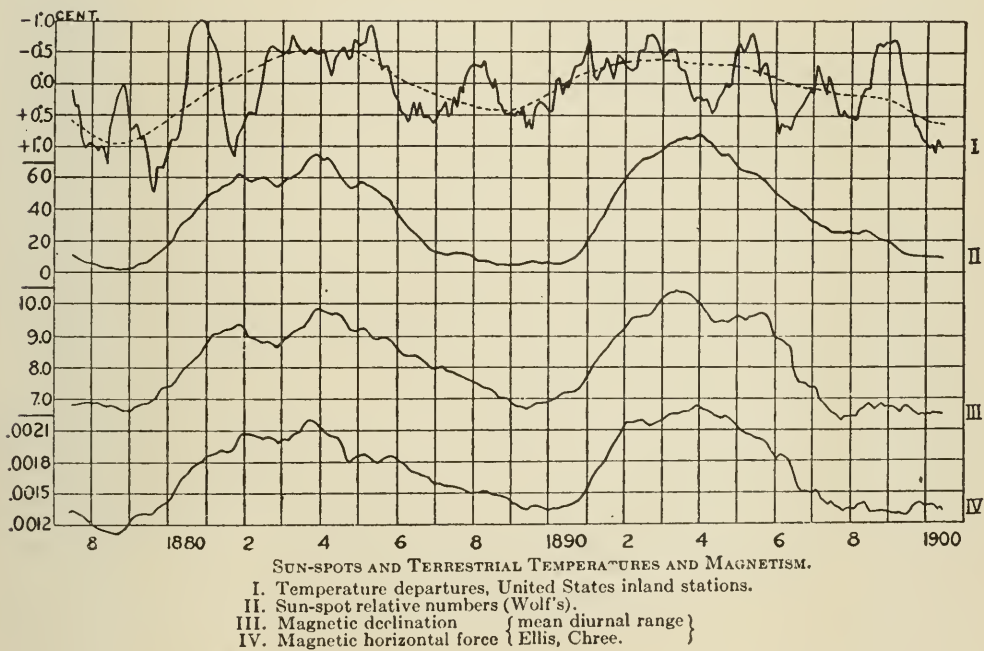
Direct solar photograph (Slocum).

interesting features may be pointed out. In the first place, note the falling off of the brightness of the disc toward the edges of the sun. In the second place, one sees in the original photograph all over the sun's surface a sort of mottled appearance, not very distinct, but yet interesting. In the third place, in this particular photograph, appear some dark spots, called sun-spots. Sun-spots were discovered by Galileo in the year 1610, soon after the invention of the telescope. They are distinguished by dark central parts, called the umbra, surrounded by a fringe of less

darkness called the penumbra. The spots shown in the present figure are very large ones, although they seem very small upon the surface of the sun. This is because of the immense diameter of the sun itself. The earth might be dropped into one of these sun-spots without much more than filling the umbra, leaving a generous space for the penumbra outside of it.

It was found by Schwabe, about the middle of the nineteenth century, that sun-spots occur most plentifully in periods of about 11 years between maxima. This may be seen by the accompanying figure, in which the second curve represents the prevalence

FIG. 2.



of sun-spots according to the so-called sun-spot numbers published by Wolfer. The two lower curves represent respectively variations in the earth's magnetic declination and in the earth's magnetic force for the corresponding years. It will be seen how exactly the sun-spot curve is reproduced in these fluctuations of the earth's magnetism, but the cause of the connection which is so apparent is not yet well understood. In the upper curve of the figure are represented the departures of temperature for the average of 17 stations in the United States, and there will be seen, although not so plainly marked, an apparent influence of the sun-spots on the temperature of the earth.

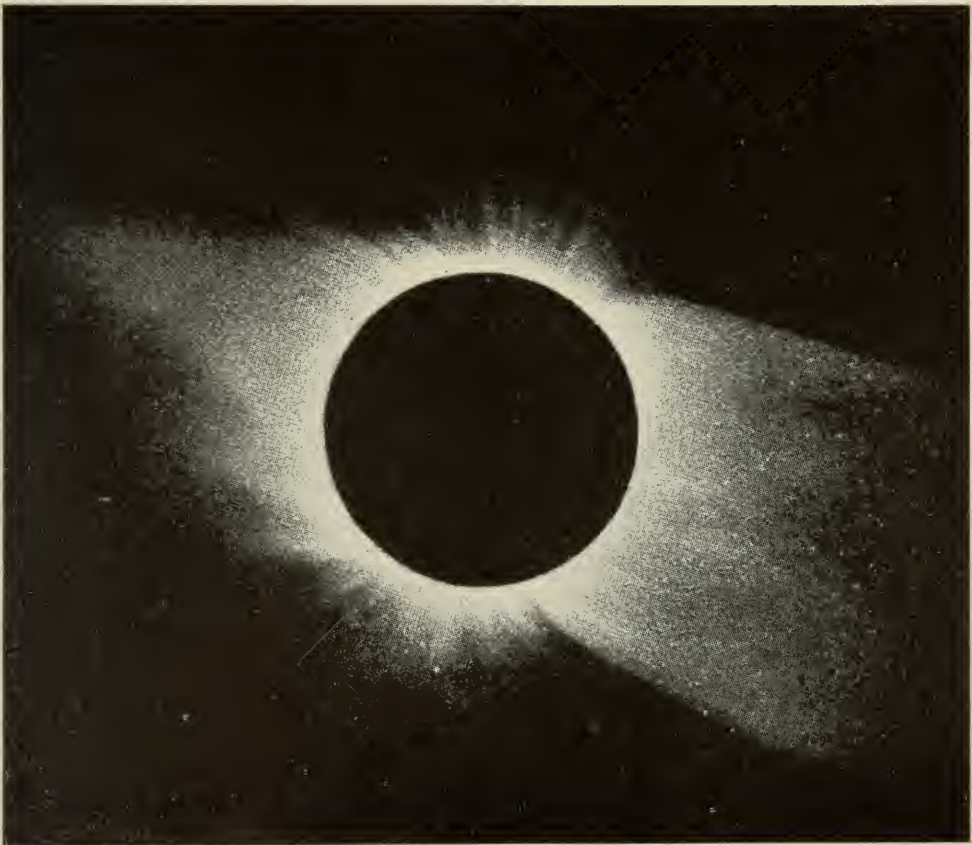
Recent work, much of it at the Mount Wilson Solar Observatory, has given us a good insight into the nature of sun-spots. They appear to be whirls of material coming outward from the inner layers of the sun toward the surface, spreading out there like a water spout. The expansion attending decrease of pressure on the gases causes a fall of their temperature, so that the sun-spots are cooler than the surrounding parts of the sun, and this is the reason why they seem dark. The whirling matter contains electrical charges, which, by virtue of their rotation, give rise to magnetic fields, as shown long ago by Rowland. The presence of magnetic fields in sun-spots has recently been established by Hale.

At certain times the moon interposes between the earth and the sun and cuts off the sunlight, so that we are able to see the objects which are surrounding the sun and usually lost by the intense glare of the sky. Such occasions are called "total solar eclipses." As the moon is but little, if at all, greater in angular diameter than the sun, the cone of shadow cast by the moon only a little more than reaches the surface of the earth, and sometimes, indeed, fails to reach it at all. When the cone reaches the earth's surface, and we have a total eclipse, there will be a belt, not more than two hundred miles wide, but sometimes several thousand miles long, upon the earth's surface, in which the total eclipse may be observed at some time of the day. Frequently the belt of totality passes over inaccessible regions of the earth, as, for instance, the North or South Pole, or falls upon parts of the ocean where it is impossible to use delicate instruments. The longest possible period of totality at any one station is 7 minutes, and in general the total eclipses average about 3 minutes in length. Thus only a very little time can be used in eclipse observations, and yet the information to be gained at such times is so valuable that observers often spend months in preparation, and travel thousands of miles to observe them.

The accompanying figures show the total eclipse of the sun. The first is from a drawing of Calvert as photographed by Yerkes Observatory observers at Wadesborough, N. C., in the year 1900, and the second is from a drawing by Mrs. Abbott from plates of the eclipse as photographed by the United States Naval Observatory parties in Spain and Africa, in the year 1905. In each photograph will be seen the corona, so-called, a pearly object

stretching out in beautiful forms to a considerable distance outside the sun. A great change, however, apparently occurred in its form between the year 1900 and the year 1905. This change is shown by other eclipse observations to be characteristic, and to always accompany the change from sun-spot minimum conditions to sun-spot maximum conditions. At sun-spot minima the solar

FIG. 3.



Solar corona, May, 28, 1900. (From drawing by P. R. Calvert from photographs by Yerkes Observatory Eclipse Expedition.)

corona extends in long equatorial streamers, while at sun-spot maximum the corona, though somewhat brighter, is not so extensive in any particular direction, but stretches almost equally in all directions.

Close up to the border of the sun there are also seen, at times of solar eclipses, bright red flames, called prominences, which are due to the gases hydrogen and calcium, with sometimes an admixture of other chemical elements. These beautiful objects

sometimes reach above the surface of the sun as much as 500,000 miles; and in some instances they have been observed to shoot up to such immense heights as this within 10 minutes of time. I say within 10 minutes of time, which implies that they may be seen at other times than during total eclipses. A method of observing them by aid of the spectroscope was devised independently by

FIG. 4.

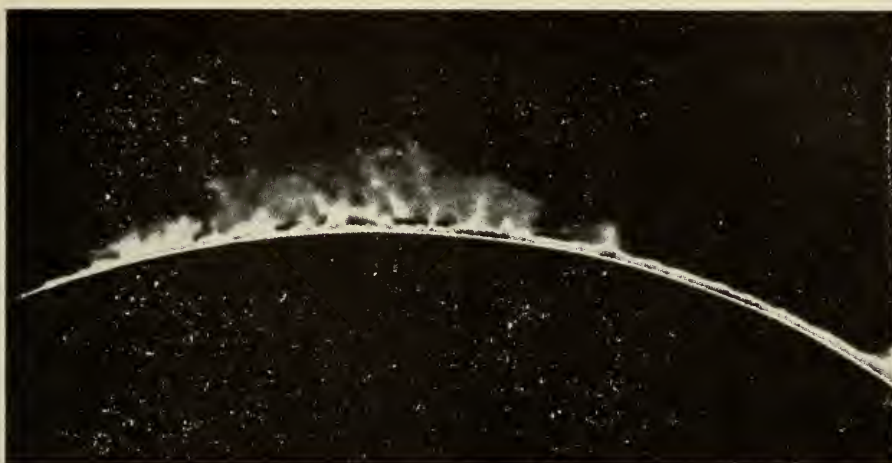


Solar corona. August 30, 1905. (From drawing by Mrs. C. G. Abbot from photographs by the United States Naval Observatory Eclipse Expedition.)

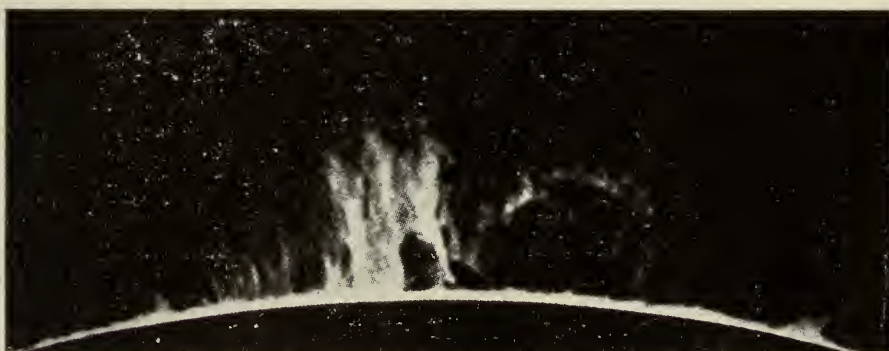
Lockyer and Janssen immediately after the eclipse of 1868, and nowadays many observatories examine them every day. A beautiful prominence is shown in the accompanying figures as photographed by Slocum at the Yerkes Observatory.

It would have seemed hardly credible to the contemporaries of Sir William, or even of Sir John Herschel, that the materials

FIG. 5.



1910, March 17, G. M. T.; 5 h. 30 m.; long. 7° ; lat. $+17^{\circ}$ to -18° .



1910, October 10, G. M. T.; 7 h. 56 m., .8.



1910, October 10, G. M. T.; 8 h. 6 m., .4.

Solar prominences (Slocum). Calcium (H) spectroheliograms.

of which the sun and stars are composed could ever be known, but by aid of the spectroscope much is learned in this respect. White light may be thought of as a complex mixture of vibrations

of the ether, so-called; that medium which is supposed to fill all space, including the interstices between the atoms and molecules of material bodies. When light passes through a prism of transparent substance, the complex vibrations are decomposed into their component parts, and we see the spectrum, in which the colors are arranged in the order, violet, indigo, blue, green, yellow, orange, red. The spectrum is by no means limited by the end of the visible red, or by the end of the visible violet, for rays which may be photographed, and which produce heat when allowed to shine upon blackened substances, exist both beyond the red and beyond the violet. Those beyond the red are called infra-red, and those beyond the violet, ultra-violet. The ultra-violet rays may be readily photographed, and by specially staining photographic plates, with organic dyestuffs, it is possible also to photograph a limited region beyond the visible red. Further progress in that direction, however, must be made by delicate electrical thermometers, or other heat-measuring instruments.

When the chemical element sodium or any of its compounds, like common salt, for instance, is placed in the flame, and the light which is given out is examined in the spectroscope, it is seen to consist of a couple of bright yellow lines. No general extension of the spectrum to include the green or violet is seen. On the other hand, if one observes the spectrum of the lime-light or the electric arc from carbon poles, it is seen to give a long band of color much like the solar spectrum, except that, whereas in the solar spectrum a great number of dark lines are seen under good conditions, in the spectra of the arc light or of the lime-light these lines will generally be absent. If, however, the vapor of metallic sodium be caused to intervene between the source of light and the slit of the spectroscope, two dark lines will be seen in the yellow, corresponding in position to the two bright yellow lines which are found by observing the light from heated sodium, or heated common salt. In short, the yellow light is absorbed by the sodium vapor at the very positions in the spectrum where that vapor would itself give off light if strongly heated. The same is true of iron and other metals. The spectrum of iron is very complicated, consisting of a great number of lines, many of them in the green. If the arc light be caused to play between iron poles, these bright green lines will be the main features of the light as observed in the spectroscope. Some of these lines are

very strong, others quite weak, so that there is often a well-marked distinction between one line and another, not only as regards its place but also as regards its intensity in the spectrum.

Now it is found on observing the spectrum of the sunlight or starlight that the dark lines are found in the same relative positions, and generally of nearly the same relative intensity, as in the bright line spectrum of the chemical elements themselves. In this way it is possible to determine what elements are found in the sun and the stars, although these bodies are so immensely distant from us. In this way we know that more than forty of the ordinary chemical elements found upon the earth exist also in the sun, and the existence of about twenty more is doubtfully indicated by the solar spectrum. Not only does the approximate correspondence in position and intensity of the spectrum lines of the sun and of the chemical elements as observed in the laboratory yield this significant result, but the slight deviations from exact correspondence in intensity and in position of the spectrum lines yield other facts not less remarkable. For instance, it was predicted by Doppler and observed in the laboratory by Prince Galitzen that the motion of a source of light toward the observer displaces its spectral lines toward the violet, and, contrawise, the motion of the source of light away from the observer displaces the spectral lines toward the red. This effect is very noticeable in the solar spectrum if one takes the light from the east and west limbs of the sun. There is a displacement of the lines of the two spectra with respect to one another, depending upon the fact that the one side of the sun is approaching the earth and the other side receding, by virtue of the rotation of the sun on its own axis.

It had long been known that the sun rotated upon its axis, because of the behavior of sun-spots, which march across the disc of the sun in a period of about fourteen days.¹ Duner, Halm, Adams, and others have observed the rotation of the sun by means of the displacement of the spectral lines. The curious fact that the surface of the sun rotates with unequal velocities, largest at the equator and smaller as we approach the poles of the sun in either direction, had been noted from sun-spot observations. This

¹ This exceeds the half-period of the sun's rotation because of the advance of the earth in its orbit at the same time.

peculiar rotation behavior of the sun's surface was investigated much more thoroughly by Adams, who followed the rotation of the sun up to solar latitude of 75° . He found that the period of rotation, as determined by the majority of the spectrum lines, varied from 24.6 days at the equator to 33.1 days at latitude 75° . However, the element hydrogen, which is situated high up in the solar atmosphere, indicated a much more nearly equal velocity of rotation at differing latitudes. The values range from 23.7 days at the equator to about 26 days at latitude 75° .

Another cause of the displacements of the spectral lines is in the pressure which exists in the solar envelope. This was investigated first by Humphreys and Mohler at Baltimore. It has since furnished a valuable means of measuring the pressure which exists in the solar envelope. For the element iron it is found to be about five times the atmospheric pressure at the surface of the earth.

Still another interesting displacement of spectral lines was found by Zeeman to be due to the presence of a magnetic field. Spectrum lines are broken up in the presence of a magnetic field into doubles or triples or still more complex groups, whose complexity of arrangement depends upon the situation of the spectro-scope with respect to the magnetic field, and on the strength of the magnetic field in which the light is produced. This peculiarity was taken advantage of by Hale, who has recently proved the existence of a magnetic field in sun-spots, and still more recently the existence of a general magnetic field over the whole surface of the sun, analogous in many respects to the magnetic field which exists over the surface of the earth.

A brilliant invention of Hale's earlier years of investigation was that of the spectroheliograph. This is an instrument for observing the sun's disc in the light of a single line of a single chemical element. It is not necessary here to explain the details of the construction or the principle of it, more than to say that it is a particular form of spectro-scope whose effect is to act as a screen to cut off all rays of the spectrum except the particular one which it is desired to observe. By the aid of this instrument the distribution of the gases of different elements over the sun's disc has been investigated, notably of the gases hydrogen and calcium. The accompanying illustration shows a photograph of a portion of the sun's disc as observed in hydrogen. The reader

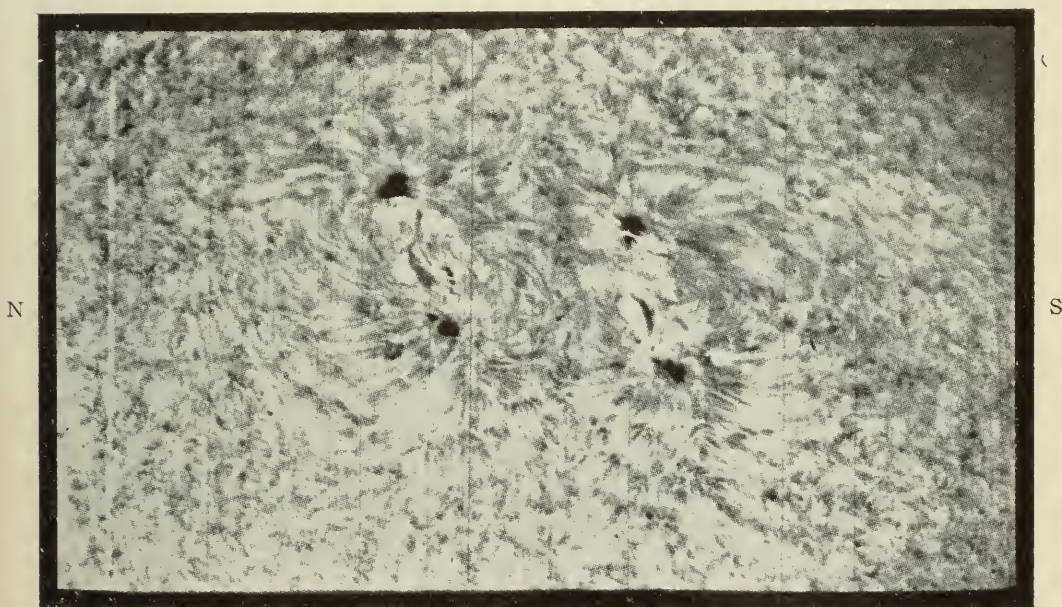
will note the very prominent detail which is shown by this illustration as compared with that shown by direct photography of the sun's surface by a telescope as given in Fig. 1. It was by the aid of the spectroheliograph that Slocum obtained the beautiful figure of the solar prominence given in the preceding illustration.

SOLAR ENERGY.

We now turn from this general consideration of what may be seen on the sun by the aid of the telescope and spectroscope

FIG. 6.

W



E

Hydrogen spectroheliogram, Ha (Ellerman). 1909, September 10, G. M. T.; 3h. 22m. P.S.T
7h. 22m. A.M.

to a discussion of the quantity of energy which the sun sends out, the distribution of it among the different spectrum rays, and the relations which it bears to the temperature of the sun, the temperature of the earth, and other terrestrial concerns. I said a little while ago that light is regarded as of the nature of a mixture of vibrations in the ether, which is supposed to be a substance existing in all space, including the interstices of the structure of the chemical elements themselves. Light is but one of the manifestations of radiation. It is merely that kind of radiation

which is visible to the eye. Just as there are some sounds which are of too high pitch for the ear to hear, and some other sounds which are of too low pitch to distinguish as sound, so there are kinds of radiation which are of too short wave-length for the eye to recognize as violet light, and others are of too long wave-length for the eye to recognize as red light. Indeed, for the longer wave-lengths of radiation the substances of the eye are not transparent, so that even if the retina should be sensitive to these rays, they could not reach the retina to effect it.

In this state of affairs it is necessary to proceed to the investigation of the energy of radiation by means of another instrument in which the radiation is caused to be absorbed by a blackened surface, and thus to produce heat, and consequently a change of temperature of the absorbing substance. Radiation is not heat. Heat is a motion of the molecules of the material substance, but radiation is a motion of vibration in the ether, which is not regarded in the same category with ordinary chemical elements. Indeed, we may go a little further and make a classification of energy. Imagine a chest of drawers in which, as sometimes happens, the letters or other papers fall over the back of the drawers, as they are pulled out, into the ones below. It is easy in that manner for the papers in the upper drawers to fall into the lower drawers, but work has to be done in order to get the papers from the lower drawers into the upper ones again. So with energy: all forms of energy may easily be transformed into heat, which is the lowest type of energy, but heat energy can only partially be transformed back again into the higher types. Of these types radiation is one of the very highest.

Now it is on the sun's radiation that a temperature suitable for life upon the earth depends. Not only that, but the peculiar properties of certain wave-lengths of the solar radiation are required for supporting plant growth, with its complex chemical reactions. All sources of energy upon the earth have been directly or indirectly produced by solar radiation. A good many investigators, among them Mr. Shuman, of Philadelphia, have endeavored to use the solar radiation commercially for the production of power, and, in fact, very satisfactory results are being obtained in this way, under Mr. Shuman's direction, from a plant in Egypt.

Evidently it is of the greatest interest to measure the quantity

of the solar radiation, the distribution of it in the spectrum, the hindrances which it suffers in passing through the earth's atmosphere, and the quantity of it available to warm the earth after it reaches the surface. This has been the principal work of the Astrophysical Observatory of the Smithsonian Institution for the last twelve years.

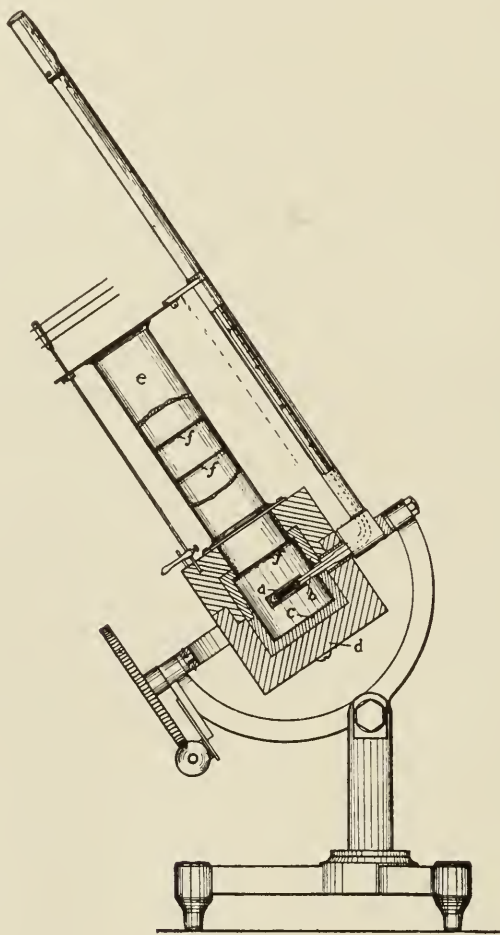
In the first place, we have to deal with the measurement of the solar radiation as a whole. For this purpose we employ what is called the pyrhelimeter, a name first devised by Pouillet, about the year 1835. He employed a blackened box, filled with water, and containing a thermometer for observing the rise of temperature in the water due to the absorption of the solar rays upon the blackened box. In our practice we have considerably developed the instrument of Pouillet, until now it comprises a silver disc enclosed in a chamber provided with a vestibule for the admission of the solar rays. The disc has inserted in it a thermometer, which is bent at right angles for convenience, and on which the rise of temperature of the silver disc due to the absorption of solar radiation is observed. The instrument is shown in the accompanying illustration (Fig. 7).

It is not possible to obtain the correct heat capacity of the pyrhelimeter in this form, so that we have reduced its measurements by comparison with what is termed the standard pyrhelimeter, in which the heat produced by the sun's radiation is carried off by flowing water. The rise of temperature in the water, due to the absorption of the solar radiation, is determined by means of an electrical thermometer. In this apparatus it is possible to introduce electrically known quantities of heat, and to measure them as if it was solar radiation which was being measured. In such test experiments it is found that as much as 99 per cent. of the heat introduced is recovered, and it is believed that the standard pyrhelimeter gives the true scale of radiation for the sun within a probable error of a half of one per cent. The silver disc pyrhelimeters have been compared against this standard, and in this way the standard scale of radiation has been diffused by the Smithsonian Institution, which has sent out about 25 copies of the standardized silver disc pyreheliometer to various countries of the world, in Europe and North and South America.

Measurements with the pyrhelimeter indicate that the maximum intensity of the sun's radiation at sea level is about 1.5 calo-

ries per square centimetre per minute. At high-level stations, such as Mount Whitney, in Southern California, at an altitude of 14,500 feet, the readings run as high as 1.7 calories per square centimetre per minute. You may ask why it is that if the intensity of the sun's radiation increases as we go up a mountain, it should be also the case that the temperature of the air at high elevations

FIG. 7



Silver disk pyrheliometer.

is lower than it is at sea level. This is due to the property of the air of almost freely transmitting solar radiation. Like a pane of glass in a window, it is not much warmed by absorbing the rays, whereas a blackened substance held in the beam of light, either upon a mountain or inside the window pane, will be very appreciably warmed.

If we could go outside the atmosphere altogether, all the

radiation which we receive from the whole sky, and which is derived by scattering, would be still in the direct sun-beam. Looking away from the sun we should see the stars shining, as if at night, and the sun's rays themselves as observed by the pyrheliometer would exceed in intensity even those observed on high mountain summits. Now the question is, What would be the intensity of the solar radiation if we could observe it outside the atmosphere, at the earth's mean solar distance? This quantity is called the solar constant of radiation, and it has been an object of investigation for the last hundred years.

As shown by Forbes, Radau, and notably by Langley, it is not possible by means of the pyrheliometer alone to estimate what the intensity of the solar radiation outside the atmosphere would be, unless the pyrheliometer itself could be raised by a balloon or otherwise to the extreme limit of the atmosphere. This latter procedure having heretofore been impracticable, it was necessary to have recourse to measurements of the solar spectrum. The defect in pyrheliometer observations consists in this: that the several rays of the solar spectrum are unequally affected in passing through the earth's atmosphere. Certain rays are almost completely removed in the higher levels of the atmosphere, so that we can by no means estimate the losses, even upon the highest mountains, unless recourse is had to determinations in the spectrum.

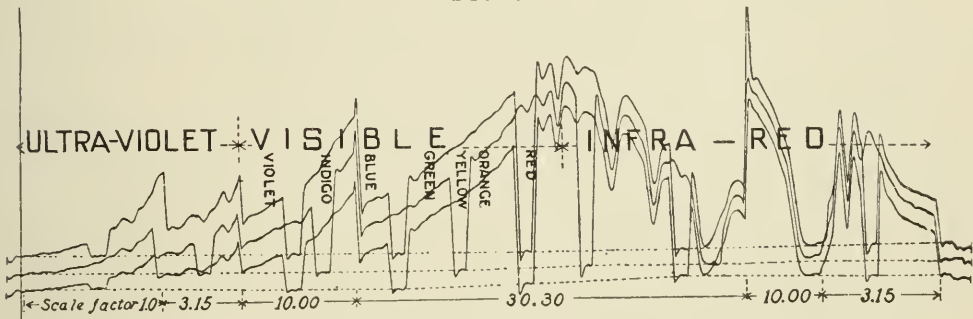
About the year 1880 the late Dr. Langley invented the bolometer. This is an electrical thermometer of great sensitiveness. It comprises two fine strips of platinum, each about one-half inch long, one-two-hundred-and-fiftieth of an inch wide, and one-two-thousandth of an inch thick. The strips are blackened on the front surface with smoke, or with platinum-black electrically deposited. These two strips, with two coils of resistance wire, form a Wheatstone's bridge, so-called. If one strip is warmed with respect to the other, and thereby its electrical resistance is increased, the effect is to cause a slight current of electricity to flow through a very sensitive galvanometer. In ordinary practice one can detect with the bolometer differences of temperature of a millionth of a degree; and in the most refined construction, with every precaution taken to avoid disturbing influences, it has been possible to observe the hundred-millionth part of a degree change of temperature.

With the bolometer, which in those days was an instrument of very uncertain behavior, and one requiring the most expert attention and great patience for its use, Langley observed the sun's spectrum in the famous expedition of 1881 to Mount Whitney, in Southern California. Like early investigators who had used the pyrheliometer alone, he observed the increase of the intensity of the sun's rays from early morning to noon, and their decrease of intensity from noon until late afternoon. This depends, as you will see, upon the fact that when the sun is low and near the horizon it shines obliquely through the atmosphere, so that its path in the air is very long, whereas at noon, when the sun is nearly overhead, the path in the air is comparatively much shorter. If one observes, therefore, the intensity of each of the spectrum rays at different altitudes of the sun, for which he knows the length of path in air, he may compute from the observed increase of intensity, attending the decrease of air path, how much the intensity would be if the path in air could be reduced to nothing at all, or, in other words, if he could go outside the air altogether. It is not possible to do this by observation with the pyrheliometer alone, as explained above, because the rays of certain spectrum wave-lengths are almost entirely removed in the upper atmosphere, and do not reach the observer at all, even if he be on a high mountain. Especially is this the case in the infra-red region of the spectrum, which is invisible to the eye, but which is of great importance as containing a large part of the sun's energy. In this region there are great water-vapor bands, where the water vapor of the atmosphere almost completely absorbs the solar rays, leaving great gaps in the representation of the sun's energy spectrum. Langley introduced the procedure of estimating for all other parts of the spectrum the intensity which would be found outside the atmosphere, but in the great water-vapor and other terrestrial bands of absorption he merely made the assumption that these would be altogether absent if he could in fact be beyond the atmosphere altogether.

After Langley became Secretary of the Smithsonian Institution he established the Astrophysical Observatory there, in order that he might carry out to greater perfection the measurements of radiation begun by him while still Director of the Allegheny Observatory in Pennsylvania. Among the first improvements introduced in Washington was the automatic recording of the results

of the bolometer by photographic means. This was a great step, so that now we are able, in the lapse of less than ten minutes, to observe the intensity of the rays of the sun of all wave-lengths, from those far beyond the violet end of the visible spectrum to those far beyond its extreme red. The accompanying figure shows the result of three such observations made on Mount Wilson, in California, at the station of the Smithsonian Institution there. These three curves represent the distribution of solar radiation in its spectrum, including the ultra-violet, visible, and infra-red rays. The great water-vapor bands above mentioned are shown in the infra-red as great depressions of the curve. Solar absorption lines are shown in the visible spectrum as smaller depressions of

FIG. 8.



Bolographs of the solar spectrum.

Air masses of observations { Upper curve, 3.0.
Middle curve, 4.0.
Lower curve, 5.2.

the curves. The three curves were taken at different hours of the morning, when the path of the solar rays in air was five, four, and three times, respectively, that which would occur if the sun were vertically overhead. The reader will notice that the curves are respectively higher and higher, especially in the violet end of the spectrum, owing to the decrease of the length of path of the sun rays in the air. At several points a change of scale of the curves is shown. This is due to the introduction in the beam of rotating sectors of different angular apertures in order to keep the record always within the limits of the registering photographic plate. If these changes of scale had not been made, the curve would run up in the edge of the red to the height of the room.

By suitable computation, by the aid of the exponential formula developed by Bouguer about the year 1760, it is possible to compute for each of the parts of this spectrum energy curve the

intensity which would be found if one were outside the air altogether. In this way one might construct a curve similar to the three shown in the illustration, which would represent the intensity of radiation beyond the limits of the atmosphere. In such curves as these the area included between the curve and the axis of zero radiation is proportional to the intensity of the whole solar beam, including all wave-lengths. This, of course, is also measurable by the pyrheliometer. Accordingly we multiply the reading of the pyrheliometer by the ratio between the area of the curve outside the atmosphere and that which is found at the observing station, and thereby we obtain the solar constant of radiation. In this process, however, we follow Langley's assumption that there will be no absorption by water vapor or oxygen in the sun itself, and therefore draw a smooth line, in our extra-atmospheric energy curve, where great atmospheric bands occur.

About 700 determinations of the solar constant of radiation have been made by the Astrophysical Observatory of the Smithsonian Institution, some at Washington at sea level; others at Mount Wilson, at an elevation of about one mile above sea level; others at Mount Whitney, at an elevation of nearly three miles; and others at Bassour, Algeria, at an elevation of three-quarters of a mile. No differences beyond the reasonable errors of measurement are found between observations made at two stations on the same day, whether made at sea level or at any of these stations, up to the elevation of Mount Whitney, 14,500 feet above sea level. Hence it appears that the method of estimating atmospheric transmission is probably sound. The mean value of the solar constant of radiation, as thus found from 700 determinations, is 1.933 calories per square centimetre per minute. By this is meant that if the sun's rays outside the atmosphere could be absorbed completely in a layer of water one centimetre (about three-eighths of an inch) thick, exposed at right angles to the solar beam, this layer of water would be warmed 1.93° C. during each minute of time. Expressed in another way, the sun's radiation outside the atmosphere would be able to melt a layer of ice 105 feet thick each year.

An extremely interesting feature of the measurements has been that they show a variation of the sun. This conclusion has been tested in every way, not only by making measurements at different altitudes, but by comparing results obtained on the same

days at Mount Wilson, in California, and at Bassour, Algeria. As these stations are separated by about one-third the circumference of the earth, it seems not possible that they could be generally influenced by local conditions in a way to disturb the measurements in the same direction at the same time. Nevertheless, the results of about 50 days of simultaneous observing at the two stations agree in showing that when the radiation of the sun is found above the normal, at the one station, it is found also above the normal at the other station, and *vice versa*. The fluctuations of the intensity of the sun's radiation outside the atmosphere thus indicated range over about ten per cent. Often within a single week, or ten days, a fluctuation of radiation as great as five per cent. is shown. The variation of the sun in these short periods appears to be irregular, both as regards the magnitude of the variation and as regards the period of it.

The measurements made at Mount Wilson, which extend over the years 1905 to 1913, indicate also a fluctuation of the intensity of solar radiation, attending the changes of the number of sun-spots. There appears to be about three per cent. increase of the solar radiation outside the atmosphere, for an increase of 100 in the Wolf sun-spot numbers. It is a very curious thing that the solar radiation increases with increasing numbers of sun-spots, whereas the temperature, which directly depends upon the solar radiation, falls with increasing numbers of sun-spots. It appears that there is, attending sun-spots, a direct and an indirect influence on terrestrial temperature. The direct influence is due to the increased solar radiation. The indirect influence is perhaps due to a change in cloudiness, but as yet is not certainly understood. These two influences are of almost equal magnitude in general, but with the indirect influence, which tends to lower temperatures, slightly predominating. It will be a research of great interest and value to determine the cause of the indirect influence.

In connection with these researches on the solar radiation the transparency of the air for light of all colors, and for invisible rays, has been determined. This is a matter of great interest to those who are studying the growth of plants, as well as to those who are interested in the propagation of signals by means of lights at sea and elsewhere.

Also, the form of the energy spectrum of the sun having

been determined, it is possible to estimate the probable temperature which exists in the sun. For it is shown that as the temperature of a source of light increases, the position of the wave-length of maximum intensity in its spectrum shifts toward the violet end of the spectrum, and from the exact position in the spectrum of the wave-length of maximum intensity the temperature of a source of light may be ascertained. In this way it appears that the sun's temperature is of the order of 6000° C., or nearly twice the temperature of the arc light. It is also possible, by means of the measurement of the solar constant of radiation, to determine the sun's temperature. In this way also values of the order of 6000° C. are found.

The surface of the sun is not equally bright from one edge to the other. This is shown plainly on solar photographs, as was pointed out in relation to the first illustration, but a more careful study of the matter is being made by the Astrophysical Observatory of the Smithsonian Institution, at its station on Mount Wilson, by the aid of the bolometer. The accompanying figure (Fig. 9) shows the observing station of the Astrophysical Observatory, and the reader will see a tower which has been erected upon it, in which is a vertical telescope for forming a large image of the sun. By stopping the clockwork, this image is allowed to drift across the slit of the spectro-bolometer. Thereby an automatic record is produced of the distribution of radiation of any selected wave-length from one edge of the sun along the diameter to the opposite edge. Such observations are shown in the accompanying illustration (Fig. 11). The distribution of radiation is given for five different wave-lengths.

It is seen that there is a marked contrast of brightness, especially for violet rays. Here the edge of the sun's disc is hardly half as bright as the centre. The contrast of brightness diminishes with the increasing wave-length of the light examined, and for the infra-red rays is comparatively small. Experiments are being made on every day on which the solar constant of radiation is determined, in order to see if there is a change of contrast in brightness along the diameter of the sun, accompanying the change of the intensity of the sun's radiation. Changes of contrast along the sun's diameter have already been found, but it is not yet decided whether they agree in point of time with the changes in the intensity of the solar radiation.

NATURE OF THE SUN.

In view of what has been said, what is the nature of the sun? It appears, in consideration of its high temperature and low density, to be a great ball of incandescent gases. Of course, the pressure is so enormous that the gases approach the density of liquids. These gases are so hot as to exceed in temperature any-

FIG. 9.



Smithsonian observatory on Mount Wilson.

thing that we have upon the earth's surface. It must not be supposed, however, that they are burning gases like the burning of illuminating gas in air. The temperature on the sun's surface is so high that in general no compounds of elements are occurring there. If the ordinary compounds, for instance, products of combustion like carbonic acid gas, should be present on the sun, the elements of which they are composed would separate, one from another, owing to the enormous temperature. As the sun

gives off radiation, it tends to cool, and it may well be asked why, in the course of the millions of years which geologists tell us have elapsed since the earth reached substantially its present temperature, the sun should not have cooled off entirely. A partial source for this immense quantity of energy was suggested by Kant and discussed at length by Helmholtz, who showed that the enormous gravitation of the sun, tending to condense the gases, and bring them toward its centre, must, for every decrease of

FIG. 10.



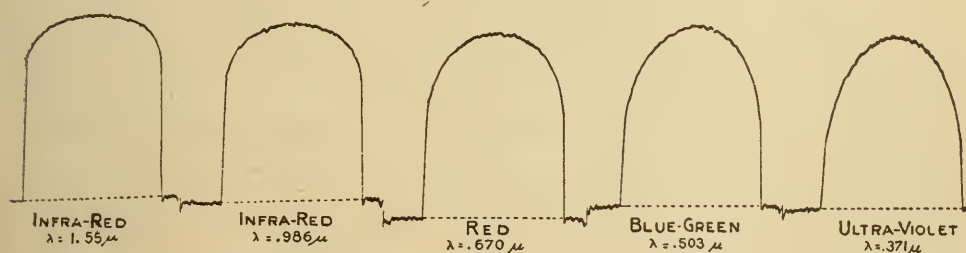
Smithsonian observatory on Mount Whitney.

temperature and consequent shrinking up of the volume of the sun, produce a certain quantity of energy. This source of the sun's energy, however, seems insufficient to account for that which geologists demand us to concede. It may be that the secret of the matter is in the breaking up of the atoms, such as is now found to occur with the element radium.

If the sun is gaseous, the question naturally arises why it presents so sharp and round a boundary. The roundness of the sun is only what would be expected in view of its gravitation.

The sharpness of its boundary seems explainable as follows: Gases, although very transparent, are not perfectly so, so that in the case of the earth the atmosphere above Mount Wilson transmits only about 95 per cent. of the yellow light. If, then, 5 per cent. of the sun's radiation in the yellow is cut off by the earth's atmosphere, it follows that a layer of the sun's gases only a few thousand miles thick would be sufficient to prevent us from seeing any deeper. This three or four thousand miles of thickness, as we look at the centre of the sun, will extend vertically downward, but at the edge of the sun we look obliquely, and there the three or four thousand miles will all be found in a layer of the sun perhaps not more than a hundred miles in thickness. In a body 800,000 miles in diameter a thickness of a hundred miles is

FIG. II.



Brightness distribution along sun's diameter for different colors.

practically negligible, certainly so for any telescopic observations which can be made from the earth, hence, naturally, the boundary of the sun is seen to be sharp.

The contrast of brightness between the centre and the edge of the sun follows at once from what has just been said. For at the centre we look far deeper than at the edge, and, naturally, see thereby gases which are much hotter than those which are perceived in the comparatively superficial layer which is seen at the sun's edge. Attending the increase of temperature there must be an increase of brightness, and this will be greater for red and infra-red rays than for violet and ultra-violet rays, in accordance with laboratory experiments on the relations of radiation and temperature. Thus the contrast of brightness between the centre and the edge of the sun will be greater in the red and infra-red than in the violet and ultra-violet.

The sun-spots appear to be whirlpools where the gases of the

interior are pouring out toward the exterior in forms similar to a water-spout. They are cooled by expansion as they reach the surface, and the partial vacuum formed in the centre of the whirl sucks in the superincumbent and very light gases, hydrogen and calcium, above the sun's surface. The magnetic field found by Hale in sun-spots is due, no doubt, to the rotation of the electrically-charged material in the spots. The solar spectrum, with its numerous dark lines, is due to the presence of the gases of the chemical elements which are found upon the earth. These gases are cooler at the boundary of the sun than they are within, where the principal part of the light comes from, hence, as noted above, the effect will be to produce dark lines on a bright background. The irregular mottled appearance of the sun's surface is probably due to differences of temperature which exist in so great a body, and thereby produce variations in brightness of different parts.

It is impossible to go further and touch upon the very interesting questions connected with the sun's place among the stars, the dependence of plant growth upon solar radiation, and the relations between the temperature of the earth and the radiation of the sun. These matters, and many details, which it has been impossible to mention in this short account, are discussed by the writer in a book entitled "The Sun," to which and to the original sources of information and to longer treatises the interested reader is invited to turn.

Crazing of Lead Glazes on Earthenware Bodies. J. A. CALLCOTT. (*Trans. Eng. Ceram. Soc.*, xiii, 49.)—Crazing may be caused by excess of some constituent in the glaze or body, by application of the glaze to too porous a body, or by incorrect firing. It is generally due to excess of soda in the glaze or of china clay in the body. Lime may be substituted for soda if opacity and dullness do not follow, a consequence which is avoided by rapid cooling from 1000° to 500° C., during which crystallization is most likely to take place. Cornish stone is a useful substitute for soda. China clay in the body may be replaced by Cornish stone or flint, or, if color be no object, by ball clay. Substitution of buff for purple Cornish stone in the body may be a cause of crazing. The function of flint is to alter the coefficient of expansion and to promote chemical combination between clay and fluxes. Vitreous bodies, usually deficient in flint, are especially liable to exhibit crazing. If the mixings are unaltered, a higher temperature or more prolonged firing is required.

THE SUBSTITUTION OF METAL TAPES AND WIRES FOR BARS IN BASE MEASUREMENTS.*

BY

WILLIAM BOWIE,

Inspector of Geodetic Work, United States Coast and Geodetic Survey.

ALL of you are familiar with the fundamental principle that it is necessary, in any accurate survey, to have the relative positions of some points known. When the area surveyed is of limited extent the positions of the controlling points may be determined by traverses of various degrees of accuracy, depending on the purpose of the survey.

When the survey is to be extended over great areas or over long distances, such as a state or a long stretch of the coast or of a river, the controlling points must be determined by the method called triangulation. It rests upon the mathematical principle that when three elements of a triangle are known, at least one of which is a side, the other three can be computed.

The usual procedure is to measure one side of a triangle as a base; then, from the observed angles of the connected scheme of triangles, compute all of the other sides through the system, using for the base of each triangle, except the first, a computed length.

It is usual, in extensive triangulations, to have direct measurements of more than one triangle side to strengthen the computed lengths and to guard against gross errors.

After the scheme of triangles has been adjusted for the accidental errors of the angles and the discrepancies in lengths between bases, the latitude and longitude of each point and the true bearing (or azimuth) of each line are computed from some initial station. For all connected triangulation in the United States, Canada, and Mexico, the initial point is the triangulation station, Meades Ranch, in the State of Kansas. Its adopted latitude and longitude and the azimuth from it to the station Waldo are called the North American Datum. The geographical positions are referred to the Clark spheroid of 1866, as expressed in metres. Its dimensions are: Equatorial radius, 6,378,206 metres; polar semi-diameter, 6,356,584 metres; reciprocal of flattening, $1/295$. This spheroid has been found to be so near the true size of the earth that, for geographical and engineer-

* Communicated by the author. Read December 30, 1913, before Section D, American Association for the Advancement of Science, Atlanta Meeting.

ing purposes in this country, it is believed that no other one need ever be substituted for it. Therefore, when a triangulation station has been computed on this spheroid and on the North American Datum its position may be considered final.

Triangulations are usually classified as primary, secondary, and tertiary, according to their relative accuracy. No longer is a triangulation classified according to the size of the triangles involved. Primary triangulation is used in extending the fundamental control over the country and in connection with accurate city surveys, such as those of New York and Cincinnati. In this class of triangulation the accuracy is that represented by an average closing error of about one second; that is, the three measured angles of a triangle will, on an average, fail to add up to 180° by only one second. Of course, in large triangles the spherical excess is considered. The direct measurement of those sides of the triangles used as bases has been a difficult problem for surveyors and geodesists until recent years. At present, the bases can be measured with great accuracy by means of tapes or wires made of the alloy of nickel and steel called *invar*.

Among the earliest forms of measuring apparatus used were wooden bars and glass tubes. These were not very satisfactory and they gave way gradually to metal bars, which apparently were first used in 1788 in Italy, and a little later, in 1798, in France.

The bars were usually made of steel or brass and they maintained their lengths most satisfactorily, but the great difficulties involved were the determination: (1) Of their exact lengths in terms of some standard unit, at some given temperature; (2) of the amount of change in length for a given change in temperature; and (3) of the exact temperature of the bars during the field measurement. The first difficulty was overcome by standardizing the bars in a room which could be maintained at a constant temperature and the coefficient of expansion was determined by standardizing the bars in the room at widely different temperatures. I believe it may be stated, without fear of successful contradiction, that the temperatures of no set of single-rod base bars of brass or steel were ever obtained during field measurements in daylight with a high degree of accuracy. Many methods of insulating and protecting the metal rod were employed, but the temperatures read from the mercurial thermometer inserted in the case did not correctly indicate the actual temperature of the rod.

A base measured with single brass or steel rod bars, with a small probable accidental error, might have a large actual error. As an example, a base measured by a set of these bars in Colorado, with a probable accidental error of only one part in 752,000, was this year remeasured with invar tapes and the difference in the two lengths was one part in 59,000.

It is probable that steel or brass single-rod bars would give more accurate results if used only on cloudy days or if they were used at night, when the temperature is apt to be more constant, for then the temperatures given by the thermometers would be more nearly those of the bars. But cloudy days in some regions are not numerous, and to have measured a base at night would have been a difficult and tedious undertaking.

In order to minimize or eliminate the effect of errors in temperature, various compound bars were devised. One type consisted of two parallel rods of different metals, such as platinum and copper, or steel and brass, the two rods of a bar having very different rates of expansion. Theoretically the average temperature could be obtained by noting the difference in length of the two components, which were arranged with suitable scales for making the comparison. This principle of differential expansion was applied in several different ways.

Other compound bars were designed to give a constant length by a compensating arrangement of the components.

Excellent results were obtained with the Bache-Wurde mann compensating bars of the U. S. Coast and Geodetic Survey, but it was found that slightly different results were obtained with rising and with falling temperatures. This trouble was minimized by having the bars standardized under each condition. The Eimbeck duplex bars of the Survey also gave a high degree of accuracy in the measurements, but they were used only a little, as the use of the tapes was begun shortly after they were made.

In the field measurements the bars were supported by portable tripods. The bars were either "line measures" or "end measures." In the first type, the length of the bar is the distance between two very fine lines engraved on the top of the bar near its ends. The successive bar lengths were referred to powerful microscopes mounted on posts set along the line of the base. In the "end measures" the length of the bar is the distance between its ends, and the procedure was to set two bars end to end and then move the rear one ahead and bring its rear end into

contact with the forward end of the bar left in place. In one of the earliest methods of measuring, the two bars were brought nearly together, and the distance between them was measured by a wedge properly graduated and standardized. The wedge was inserted between them and the points of contact of the bar ends on the wedge would enable the distance between the bars to be determined accurately. These small distances would be added to the whole number of bar lengths as set ups. The usual and better method of making the contact of the two bars was to have a sleeve fit over one end of each bar, the sleeve being connected with the bar by a spring. The bar was normal when a graduation on the sleeve coincided with a graduation on the bar. A slow-motion device enabled the operator to move the forward rod in its case until the contact with the rear bar was perfect and the two graduations on the bar and sleeve coincided. This procedure was repeated throughout the length of the base.

The only bar used in the United States, and probably in the world, which will give entire satisfaction in so far as accuracy is concerned, is a "line measure" called the "iced-bar apparatus" of the Coast and Geodetic Survey, which was designed by Dr. R. S. Woodward.¹ During measurements this bar is placed in a trough which is filled with crushed ice. Thus the bar is kept at a uniform and definite temperature, that of melting ice. Of course, measurements cannot be made when the temperature of the air is below the freezing-point. The trough is mounted on a carriage which runs along a portable track. The successive bar lengths are referred to microscopes placed on posts set along the base. The cost of using this bar is great and it has been and is now used only for the purpose of standardization of other apparatus, and for this it is unexcelled.

Steel wires and tapes were used in general surveying long before they were used for the measurement of primary base lines. They were, apparently, first used successfully for bases by Professor Jäderin, of Sweden, about 1882.² Tapes were experimented with at the Holton Base, Indiana, in 1891,³ and

¹ Described in detail in Appendix 8 of the Coast and Geodetic Survey Report for 1892.

² See Appendix 5, Coast and Geodetic Survey Report for 1893.

³ See Appendix 8 of the Report of the Coast and Geodetic Survey for 1892. See also Appendix 3 of 1901, Appendix 4 of 1907, and Appendix 4 of 1910, for the history of measurements of primary bases with tapes, by the Coast and Geodetic Survey.

found to be as accurate, when used at night, and much more economical than bars. Tapes were used in 1893 and 1897 in measuring the bases at St. Albans, W. Va., and at Versailles, Mo. In 1900-01 steel tapes of 100-metre and 50-metre lengths were used in connection with the Eimbeck duplex bars in the measurement of nine primary bases on the 98th meridian. One-fifth of each base was measured with the bars, and at each base 1 km. was measured with the bars and each of the tapes. The result of this campaign proved conclusively that the tapes used at night gave an accuracy as great as that obtained with the best bars.

In 1906 the Survey tested tapes made of the alloy of nickel and steel (called *invar*) by measuring six primary bases with both steel and invar tapes. The invar tapes gave results of even greater accuracy than the steel tapes, although the former were used in daylight, while the latter were used at night. All of the tapes were 50 metres in length, this length having been found more satisfactory than 100-metre tape during 1900-01.

The average coefficient of expansion of the invar tapes used by the Survey is only .0000004 per degree Centigrade, or about one-twenty-fifth that of steel. Having available a metal with such a low coefficient of expansion, the great problem in base measurement has been solved. Bars of this metal would no doubt give a measurement almost without error, but invar tapes give results which have actual errors little or no greater than one part in one million, and, as a base can be measured with tapes for 35 per cent. or less of the cost of bar measurements, it is practically certain that no more base lines will be measured with bars. Tapes have the additional advantage that they may be used over broken ground and steep slopes where bars could not be used.

That invar tapes hold their lengths in a remarkable manner is indicated by the data in the following table for tapes which have been used on all primary bases measured in 1909 and later by the Coast and Geodetic Survey. The lengths given result from six standardizations at the Bureau of Standards.

SUMMARY OF TAPE VALUES.

The following is a table showing, for each of the four tapes, the length as determined by six different standardizations, the probable error of each determination, the mean of the results from the six standardizations and the residuals. The values given are for the lengths of the tapes when resting upon three

points of support and subjected to a fixed tension of 15 kilograms. In order to make the values comparable, they have all been reduced to a common temperature, namely, 21.2° C.

VALUES OF TAPES WITH THREE SUPPORTS
• At temperature of 21.2° C.

Date of standardization.	$T_{516} =$			$T_{517} =$		
	50m. +		v	50m. +		v
	mm.	mm.	mm.	mm.	mm.	mm.
January, 1909.....	9.542	±0.017	-0.044	9.735	±0.018	+0.081
May, 1909.....	9.454	±0.028	+0.044	9.782	±0.025	+0.034
March, 1910.....	9.415	±0.017	+0.083	9.738	±0.015	+0.078
March, 1912.....	9.473	±0.029	+0.025	9.869	±0.022	-0.053
January, 1913.....	9.519	±0.016	-0.021	9.919	±0.016	-0.103
October, 1913.....	9.587	±0.020	-0.089	9.853	±0.017	-0.037
Mean.....	9.498	.....	.....	9.816	.....	.....

Date of standardization.	$T_{521} =$			$T_{522} =$		
	50m. +		v	50m. +		v
	mm.	mm.	mm.	mm.	mm.	mm.
January, 1909.....	9.750	±0.018	+0.175	10.543	±0.019	+0.068
May, 1909.....	9.835	±0.021	+0.090	10.566	±0.024	+0.045
March, 1910.....	9.878	±0.015	+0.047	10.593	±0.018	+0.018
March, 1912.....	10.009	±0.021	-0.084	10.644	±0.017	-0.033
January, 1913.....	10.034	±0.016	-0.109	10.664	±0.016	-0.053
October, 1913.....	10.047	±0.018	-0.122	10.655	±0.020	-0.044
Mean.....	9.925	.....	.....	10.611	.....	.....

This table gives very valuable data as to the constancy of the lengths of the invar tapes. The total ranges for four years in the lengths of the various tapes are :

Tape No.	Total range, mm.	Proportion.
T_{516}	0.172	1 part in 290,000
T_{517}	0.184	1 part in 270,000
T_{521}	0.297	1 part in 170,000
T_{522}	0.121	1 part in 410,000

The differences in length between the values resulting from the first and last standardizations are :

Tape No.	Range, mm.	Proportion.
T_{516}	0.045	1 part in 1,110,000
T_{517}	0.118	1 part in 420,000
T_{521}	0.297	1 part in 170,000
T_{522}	0.112	1 part in 450,000

Each of the tapes was longer at the time of the last standardization than at the first one, the average increase being 0.143 mm. or one part in 350,000. These changes are within the possible effect of the accidental and constant errors of standardization, except in the case of T_{521} . That tape shows a continuous increase from May, 1909, to October, 1913, but the maximum change in the length of this tape between any two consecutive standardizations is only 0.131 mm. (March, 1910, to March, 1912), or one part in 380,000. The maximum change between two consecutive standardizations for T_{516} is 0.088 mm., or one part in 570,000; for T_{517} it is 0.131 mm., or one part in 380,000 (the same as for T_{521}); and for T_{522} it is only 0.051 mm., or one part in 980,000.

Tape T_{522} was carried to the field by each party measuring the bases on the Texas-California arc and on the 104th meridian, but in no case was it used in the measurements. In fact, it was never unreeled in the field. Therefore any change in length of that tape has been due to other causes than those incident to the use of tapes in the field during measurements.

The data in the table on page 670 indicate a remarkable constancy in the values of the lengths of the tapes, considering the fact that three of them were used in the field in the measurement of six bases, totalling about 156 kilometres of single measures, about 52 kilometres for each tape. It may be stated also that the invar tapes are not so susceptible of injury during field work as was supposed to be the case soon after their introduction. Each of the base parties which used the tapes under discussion had only two members who were skilled in the use and treatment of tapes, the other persons in the party being unskilled men. The members of each party were cautioned to use every care in handling the tapes, but, even so, it seems remarkable that not one of the tapes has been injured.

Invar wires are used in some of the other countries with great success. The advantages of wires over tapes about equally balance the advantages of the tapes over the wires. Each type of apparatus will give results far greater in accuracy than that required. The wire is less affected by the wind. The tape is more easily reeled and unreeled than the wire. The wire may become twisted without detection, while this seldom happens with the tape. The wire seems to be more subject to kinks than

the tape. Owing to the lesser thickness of the tape, a smaller diameter may be used for its reel than for the reel of the wire.

The method of supporting the tape or wire during measurements, of applying the tension, and of marking successive lengths varies greatly. Each method has its advocates and special advantages. The method employed in the Coast and Geodetic Survey is to set stakes firmly, throughout the length of the base. At 50-metre intervals (the length of the tape) a stake four inches in cross-section is used. The intermediate supports are nails driven horizontally into stakes set just off the line. Usually only one intermediate support is used and, except in rare cases, its top is in a straight line with the tops of the two end supports. The tape lengths are transferred to copper strips nailed to the tops of the end supports, the strips being of the same thickness as the sleeves of the tape which carry the graduations. The tension is given by a spring balance attached to the stretcher.⁴ A line of levels is run over the base in both directions to get the grades from which corrections to give the horizontal distance are computed. The setting of the stakes and the levelling may be done in even strong winds, while the calmest days are utilized for the measuring with the tapes.

The base party usually consists of six persons and only one needs to have had previous experience in the work. In fact, the measurement of even a primary base is so simple an operation that this work is now considered a mere incident of the triangulation and is done by the triangulation party. This plan has two decided advantages: first, the lengths of the bases will be known when the triangulation of an arc has been completed; and, second, the base work can be done at much lower cost than where a party is especially organized and outfitted for measurement of bases.

The average field cost of measuring a base by the triangulation party is about \$50 per kilometre. The cost by special parties may be fifty per cent. greater than this. The cost of the measurements with base bars varied greatly, but the minimum was several times greater than that with the tapes.

It is evident from this sketch of apparatus and methods employed in base measurements that tapes and wires have replaced bars. Bars from now on will be found in museums and should have a prominent place only in histories of geodesy.

⁴ See Appendix 4, Coast and Geodetic Survey Report for 1910.

REFRACTIVE INDEX AND DENSITY.*

BY
IRENE MAUD MATHEWS.

THE relation between the refractive index of a substance and its density is a problem of no recent origin—and yet it is one of modern interest, for one form of the relation is a deduction from the electron theory of matter, of all the greater importance because of its tangibility from a practical point of view. The earliest theory was, μ being the refractive index, d the density,

$$\frac{\mu^2 - 1}{d} = \text{constant} \dots\dots\dots (1)$$

This was supported by Newton. He remarks: "If light be swifter in bodies than *in vacuo* in the proportion of the sines which measure the refraction of the bodies, the forces of the bodies to reflect and refract light are very nearly proportional to the densities of the same bodies, excepting that unctuous and sulphurous bodies refract more than others of the same density." Newton's formula was established by Laplace on the emission theory, and, as one would expect, it has been definitely refuted by experiment. The anomalous behavior of the sulphur compounds, on the other hand, is both admitted and unexplained.

On the electron theory we have

$$\frac{\mu^2 - 1}{(\mu^2 + 2)d} = \text{constant} \dots\dots\dots (2)$$

The only serious rival of this is Gladstone and Dale's empirical relation;

$$\frac{\mu - 1}{d} = \text{constant} \dots\dots\dots (3)$$

though Magri¹ has also considered the relation

$$\frac{\mu^2 - 1}{(\mu^2 + 1)d} = \text{constant},$$

finding it somewhat incorrect.

As the density of gases and vapors can be varied so much more easily than that of solids and liquids, it is experiments on

* Communicated by Prof. James Barnes, Bryn Mawr College.

¹ *Phys. Zeit.*, 6, 1905, p. 629.

gases that form the best test of the various theories. The earliest experiments were with atmospheric air. Biot and Arago used a hollow prism, filled with air, and observed, through a telescope, the shift of a distant mark seen through the prism, as the pressure of the air was altered. As they neglect dispersion, their results are only a rough approximation and can in no way distinguish between the three relations (1), (2) and (3); however, (2) was not known till about 1880, when L. Lorenz deduced it on the elastic solid theory of light—for the quantities $(\mu^2 - 1)$, $\frac{\mu^2 - 1}{\mu^2 + 2}$ only differ from a numerical multiple of $(\mu - 1)$ by terms of the order $(\mu - 1)^2$. For ordinary air $\mu - 1 = .0003$ approximately, so that $L(\mu - 1)^2 = 9 \times 10^{-8}$.

The first to take account of dispersion was Ketteler.² He used a Jamin interferometer, with two equal glass tubes (40 mm. long) between the plates, and sodium, lithium, and thallium flames as his sources.

If l = length of either tube,

λ_1 = wave-length of light used in the air in the first tube,

λ_2 = wave-length of light used in the air in the second tube,

λ_0 = wave-length of light used in free space.

Then $l = n_1 \lambda_1$ say

$$= n_2 \lambda_2$$

$$= \frac{n_1 \lambda_0}{\mu_1} = \frac{n_2 \lambda_0}{\mu_2} \quad \mu_1, \mu_2 \text{ being the respective refractive indices.}$$

$$\therefore \mu_1 - \mu_2 = \frac{\lambda_0}{l} (n_1 - n_2)$$

Ketteler varied the pressure of the air in one of the tubes and counted the number of interference bands that passed,—*i.e.*, $(n_1 - n_2)$, assuming the tubes equal, and found that the relation

$$n_1 - n_2 \propto (p_1 - p_2)$$

always held for all pressures, p , used—or with the above

$$\frac{\mu_1 - \mu_2}{p_1 - p_2} = \text{constant}$$

$$\text{or } \frac{\mu_1 - \mu_2}{d_1 - d_2} = \text{constant, assuming Boyle's law.}$$

If one of the tubes is evacuated, this becomes

$$\frac{\mu - 1}{d} = \text{constant.}$$

² *Pogg. Ann.*, 124, 1865, p. 390.

Ketteler points out that the difference between (1) and (3) is within his experimental error. Besides air, he used carbon dioxide, hydrogen, cyanogen, and sulphur dioxide, finding the same result to be true of each gas.

Mascart³ performed more accurate experiments, using sodium light and Fizeau's biplanes to observe Talbot bands. First he varied the pressure of the air in one of his tubes, keeping the temperature constant. Mascart found that the number of bands passing as the pressure changed from p_1 to p_2 was proportional to

$$(p_2 - p_1) \left(1 + b \frac{p_1 + p_2}{2} \right)$$

or $\mu_2 - \mu_1 = a (p_2 - p_1) \left(1 + b \frac{p_1 + p_2}{2} \right)$ a, b , being constants.

Now, according to Regnault, the relation between density and pressure, up to 8 atmospheres, neglecting p^3 , is

$$d = Ap(1 + Bp)$$

or $d_2 - d_1 = A(p_2 - p_1)[1 + B(p_1 + p_2)]$

where A, B , are constants, $d_1, p_1; d_2, p_2$, being corresponding values of d, p .

Up to 6 metres of mercury, Mascart found $\frac{b}{2} = B$ when the temperature was constant. Thus his relation for refractive index in terms of pressure, combined with Regnault's results for density in terms of pressure up to p^2 term, proves the truth of relation (3) in opposition to (1). He checks his results by using four cadmium lines as sources. On the other hand, varying the temperature, he found that the relation (3) was not accurate for

$$\mu - 1 = (\mu_0 - 1)(1 + \beta t)$$

where β is *not* the coefficient of expansion of air. There is not, however, sufficient evidence that Mascart has accurately performed all the necessary corrections for the effects of change of temperature on the dimensions of his apparatus. Besides air, he experimented on nine other gases.

Von Lang⁴ next takes up the question, discussing Fizeau's recalculation of Biot and Arago's results, as well as Mascart's results. He used a spectrometer whose prism is enclosed in a

³ *C. R.*, 78, 1874, pp. 617 and 679; 86, 1878, p. 321.

⁴ *Pogg. Ann.*, 153, 1874, p. 448.

vessel heated by hot water, and calculates the refractive index of air for every 5° from 0° to 100° C., taking precautions against the variation in the dimensions of his apparatus due to change of temperature.

Von Lang finds for sodium light

$$\mu = \mu_0 - 0.000000905t$$

$$\text{or } \mu - 1 = 0.0002923(1 - 0.00310t)$$

Mascart gets

$$\mu - 1 = 0.0002923(1 - 0.00383t)$$

Von Lang misquotes his result.

But the coefficient of expansion of air is .00367; thus neither of the results confirms formula (3), but their discrepancies are in different directions.

Shortly after this L. Lorenz⁵ did some very striking work, both theoretical and practical. To obtain the relation between the refractive index of a substance and the density for a constant wave-length, he assumes that the body is isotropic and consists of spherical molecules between which the light is propagated with the same velocity as in free space.

His differential equations are

$$\text{curl. curl } V = \frac{1}{\omega^2} \frac{\partial^2 V}{\partial t^2}$$

V being a vector, ω a rapidly varying function of the coördinates (x, y, z) in the body, and becoming a constant in free space. He treats the case of a plane wave of infinite wave-length, and concludes

$$\frac{\mu^2 - 1}{\mu + 2} v = \frac{\mu_i^2 - 1}{\mu_i^2 + 2} v_i$$

where v is the volume of unit mass of the substance, v_i the specific volume of the molecule, μ_i the refractive index for light in the interior of the molecule, assumed constant for the molecule. He has, therefore, established formula (2) for all changes of density, whether accompanied by a change of temperature or not—provided the internal condition of the molecule is unchanged. Lorenz is careful to state that the truth of his

⁵ *Wied. Ann.*, 11, 1880, p. 70.

hypotheses can only be judged by the experimental determination of $\frac{\mu^2-1}{(\mu^2+2)d}$ for different states of the same substance.

His experiments were conducted with the Jamin interferometer. He finds that for sodium and lithium light the refractive index of water between 0° and 30° C. obeys either of the laws (2) or (3), which are indistinguishable. But his crucial experiments were those by which he measures the refractive indices of seven different fluids in the liquid and gaseous states, and finds the law (2) to be considerably superior to (3), the greatest deviation being 5 per cent. Finally, he considers the modification of the law (2) for finding the refractive index of a compound from those of its constituents. This is interesting in the light of recent experimental work.

Shortly after L. Lorenz had deduced the law (2), H. A. Lorentz obtained it quite independently on the electromagnetic theory of light: he gives a modification of his original proof in his "Theory of Electrons."

The superiority of Lorenz's formula to formula (3) for substances in the liquid and vapor states was also demonstrated by Bleekrode⁶ for eleven different fluids.

Quincke⁷ experimented with fluids under hydrostatic pressure, measuring directly their compressibility and counting the number of interference bands which pass under the same circumstances—thus obtaining optically a measure of the compressibility. His conclusion is that (3) agrees with experiment, but that (1) and (2) do not.

Benoit⁸ used Fizeau's apparatus for measuring the expansion coefficient by means of Newton's rings, and showed the accuracy of the law (3). L. Lorenz's result was also confirmatory, for he obtained the reduction factor $(1-0.00368t)$, while Mascart's and Von Lang's results were negative.

Chappuis and Rivière⁹ worked with carbon dioxide and cyanogen at 21° C. for different pressures up to 19 atmospheres. They concluded that as far as the p^2 term the laws (2) and (3) hold equally.

⁶ *Proc. Roy. Soc.*, 37, p. 339.

⁷ *Phil. Mag.*, 5, 17, 1884, p. 65.

⁸ *Mem. du Bureau International des Poids et Mesures*, 6, 1888.

⁹ *C. R.*, 103, p. 37.

Unlike all previous as well as all subsequent writers, Sutherland¹⁰ claims that the law (3) is not merely empirical, but has a theoretical foundation. He gives a proof of it which, apparently, has not convinced many people. Moreover, he attacks L. Lorenz's mathematics on what would seem to be unjustifiable grounds. For, while considering a very large wave-length so as to eliminate dispersion, Lorenz states that the refraction of the molecule is *not* small.¹¹ Thus the function ω , which represents the velocity of light in free space, becomes within the body a very rapidly varying function of the coördinates (x, y, z). Lorenz then *does* provide for a change of wave-length in passing from ether into matter; his only stipulation is that this change is the same for all molecules of the body, and that in the interstices the wave-length is the same as in free space.

A new experimental method was introduced by Kayser and Runge.¹² They used a Rowland concave grating, and placed a hollow metal prism filled with air between the grating and the photographic plate, so that one-half only of the light passed through the prism. They therefore obtained simultaneously two spectra: in one, half the line showed in its usual position; in the other, the remaining half was shifted as soon as the density of the air in the prism was changed. Their experiments are extremely careful and cover a range of temperature from 10° to 17° C. and an excess of pressure of the air in the prism of 8 m. mercury. Their conclusion, both from their own and from previous researches, is that the law (3) is rigorously true.

After the Rowland grating, the next instrument used was the Michelson interferometer. Gale¹³ let the two beams pass through tubes, one of which was almost evacuated. The pressure of the air in the other was gradually reduced and the number of interference bands passing was counted. He concluded that the laws (2) and (3) are indistinguishable for the pressures used, and that any departure from either must be within 1 per cent.

In view of the anomalous results as to the truth of the law (3) for different temperatures, George W. Walker¹⁴ repeated

¹⁰ *Phil. Mag.*, 5, 27, 1889, p. 141.

¹¹ *Wied. Ann.*, 11, 1880, p. 71.

¹² *Wied. Ann.*, 50, 1893, p. 293.

¹³ *Phys. Review*, 14, 1902, p. 1.

¹⁴ *Phil. Trans. A.*, 201, 1903, p. 435.

the experiments with the Jamin interferometer. He obtained the ratio

$$\frac{\text{number of bands passing}}{\text{change of pressure}} \quad .$$

for about six different pressures and constant temperature; and then repeated for another temperature. This was done for 16 temperatures, varying from 10° C. to 100° C. He corrected for the change in length of his tubes, which were of brass, and about 100 c.m. long, taking as the coefficient of expansion of brass 0.000019. He then compared the ratios:

$$\frac{\text{Bands}}{\text{pressure}} (1 + .00355t); \quad \frac{\text{Bands}}{\text{pressure}} (1 + .00360t); \quad \frac{\text{Bands}}{\text{pressure}} (1 + .00365t),$$

deciding in favor of the middle one, giving a coefficient of expansion $.00360 \pm .00003$.

A large enough difference of pressure to distinguish between (2) and (3) was at last obtained by Magri.¹⁵ He focussed the light from a mercury vacuum arc on the plates of a Jamin interferometer, and, varying the pressure up to about 200 atmospheres, he counted the number of bands passing. The gas was compressed in a large vessel, which was connected to an instrument, for measuring the density, as well as to the interferometer tube. Magri rejects relation (1) and finds (3) is little better, preferring $\frac{\mu^2 - 1}{(\mu^2 + 1)d} = \text{constant}$ to either. H. A. Lorentz points out in his "Theory of Electrons" (English edition, p. 146) that Magri's results agree well with (2).

Let us consider what difference we should expect between (2) and (3), as μ varies. Putting $\mu = 1 + \epsilon$ where ϵ is small

$$\begin{aligned} \frac{\mu^2 - 1}{\mu^2 + 2} &= \frac{(1 + \epsilon)^2 - 1}{(1 + \epsilon)^2 + 2} \\ &= \frac{2\epsilon + \epsilon^2}{3} \left(1 + \frac{2\epsilon + \epsilon^2}{3} \right)^{-1} \\ &= \frac{2}{3} \epsilon \left(1 + \frac{\epsilon}{2} \right) \left[1 - \frac{2\epsilon + \epsilon^2}{3} + \frac{(2\epsilon + \epsilon^2)^2}{9} \right] \text{ neglecting } \epsilon^4, \text{ etc.} \\ &= \frac{2}{3} \epsilon \left(1 + \frac{\epsilon}{2} \right) \left(1 - \frac{2}{3} \epsilon + \frac{\epsilon^2}{9} \right) \\ &= \frac{2}{3} \epsilon \left(1 - \frac{\epsilon}{6} - \frac{2}{9} \epsilon^2 \right) \end{aligned}$$

¹⁵ *Phys. Zeit.*, 6, 1905, p. 629.

Thus neglecting ϵ^2 , we see that (2) and (3) are indistinguishable. This holds at atmospheric pressure, and in fact, up to about eight atmospheres. If, for example, $\mu = 1.0003 = 1 + \epsilon$, we have

$$\begin{aligned}\frac{\mu^2 - 1}{\mu^2 + 2} &= \frac{2}{3} (\mu - 1) (1 - .00005) \\ &= \frac{2}{3} (\mu - 1) \text{ to within 1 in 10,000.}\end{aligned}$$

Some very interesting work has been done by C. Cuthbertson¹⁶ on the refractive indices of the elements. He used the Jamin interferometer, placed a weighed quantity of the substance to be examined in one of the tubes, and evacuated and sealed off both tubes. He then heated the tubes in an electric furnace, counting the bands as they passed, until all the substance was vaporized. Later he had his furnace in two parts so that the vapor could be quickly condensed, by pouring cold water over the exposed centre of the tube, and heated up again in a few minutes; the counting process, therefore, became a question of minutes instead of hours. His earlier experiments aimed at a 1 per cent. accuracy, and he specially noticed a spurious starting effect, explained as due to unequal heating. It may be some such effect as this that has produced the contradictions in the optical coefficient of expansion. He calculates the value of μ for the density at which the number of atoms of the element per unit volume equals the number of hydrogen atoms in unit volume at 0° C. and 760 mm. pressure. The density of the vapor in the experiment is found by dividing the volume of the tube by the weight of the element volatilized. Cuthbertson calculates the value of the refractive index of various compounds, knowing those of the constituents, and compares the result with experiment. In some groups there is a good agreement; but in the case of the sulphur compounds we have notable exceptions.

Thus for sulphur dioxide we should have $(\mu - 1) 10^6 = 825$. But experiment gives 661.

He finds that the values of $(\mu - 1)$ for the elements of the nitrogen oxygen halogen and argon groups are to one another in certain simple numerical ratios. It should be noted that as μ is of the order 1.002, $\frac{\epsilon}{6} = .0003$. Hence, as shown above to

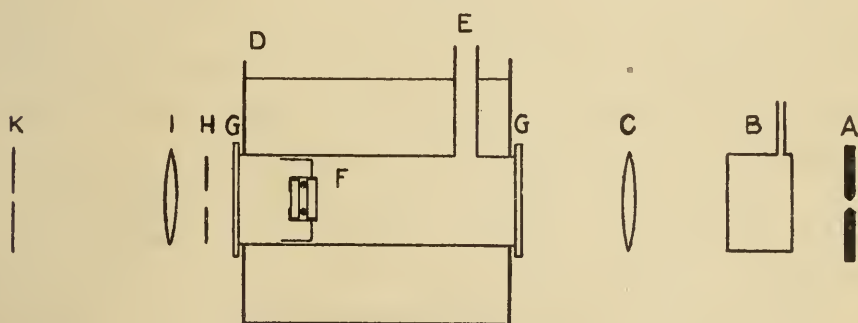
¹⁶ *Phil. Trans. A.*, 204, 1905, p. 323; 207, 1907, p. 135. *Proc. Roy. Soc.*, 76, 79, 80, 81, 83, 84.

within an accuracy of 1 in 1000, $\frac{\mu^2-1}{\mu^2+2}$ is identical with $\frac{2}{3}(\mu-1)$, and the above ratios are probably those of the number of dispersion electrons in the atom; also we have the experimental verification of the Lorenz formula for the refraction index of a compound.

The sum total, then, of the evidence is this: The choice lies between (2) and (3)—and for low densities they are indistinguishable. Formula (2) has unquestionably the advantage on theoretical grounds. As regards experiment, it is supported (a) by Magri's experiments at high pressures, (b) by the experiments of Lorenz and Bleekrode on substances in the liquid and vapor states, and (c) Cuthbertson's experiments on compounds on the whole support the relation deduced from (2).

On the other hand, there is a remnant of doubt as to whether

FIG. 1.



either (2) or (3) holds when the temperature varies. The experiments of Lorenz, Benoit, Kayser, and Runge support them; those of Mascart, Von Lang, and Walker do not. Dr. Barnes suggested to the writer that she should make use of the instrument least affected by temperature variations,—namely, the Fabry and Perot interferometer,—and measure the refractive index of air, in the first place, and then of oxygen, for different pressures at the same temperature and then at different temperatures. Another important advantage of this interferometer is that it is preëminently adapted for work in the ultra-violet region, while for all wave-lengths, since the calculations are made from photographic measurements, it eliminates the error due to a miscount of the bands passing. These experiments, however, were only just started.

The light from an arc *A*, Fig. 1, of copper zinc alloy after

passing through a water bath *B*—which absorbed the heat rays—was focussed by a lens *C* on the plates of the Fabry and Perot interferometer, which was in a hollow chamber *F* of a metal vessel *D*. The central rays, after traversing the interferometer and the aperture in the screen *H*, were focussed by the lens *I* on the slit *K* of a Hilger constant deviation spectroscope, giving an image consisting of the usual spectral lines crossed by circular black rings, part of which were only visible (except for the central small dark circle, which was entirely visible if the centre were black). The vessel *D* was cubical in shape, with a cylindrical tunnel *F* through the centre. This tunnel *F* was completely cut off from the rest of the vessel, a pipe *E* leading out of it; when its ends were covered with glass plates *G*, sealed on with wax, it formed an air-tight chamber, and the pipe *E* connected it with the column of mercury, which measured the pressure, as well as with the pump. The vessel *D* was filled with oil to maintain the air within the tunnel *F* at constant temperature. A thermo-regulator kept the temperature of the oil constant within 0.1° . The ultimate test of the constancy of the temperature of the air in *F* is the sharpness of the rings in the photograph.

The interferometer plates were silvered during the early exposures by means of the two well-known solutions—(*a*), of silver nitrate and ammonia, (*b*) of silver nitrate and Rochelle salt. After the exposure series numbered 6, another solution was used, the silver being deposited by the agency of formaldehyde. After being silvered, the plates were pressed on three steel balls held in a ring (the balls projecting beyond the ring), the pressure being exerted by three pressure screws. An area rather less than a square centimetre of the plates was exposed. The plates were placed with extreme care in the chamber *F*, the final adjustments made, and the glass plates *G* sealed on. Another adjustment requiring great care was the position of the lens *I*, which must be placed so that the rings are sharply focussed on the slit of the spectroscope.

Preliminary experiments determined carefully the magnification of the spectroscope, the focal length of the lens *I*, and the distance between the plates. The magnification of the spectroscope was found by placing a small piece of ruled glass across the slit and photographing the rulings, and measuring carefully

the rulings both on the glass and the photographic plate. This gives the ratio

$$\frac{\text{diameter of ring on slit}}{\text{diameter of ring on photographic plate}} = k.$$

The focal length f of the lens I was found by placing it on the revolving table of a spectroscope, of which the collimator was fixed, adjusted for parallel rays, rotating it through a small angle, and photographing the image of the slit. Then

$$= \frac{d}{\tan \theta}$$

when d is the linear shift of the image for a rotation θ . This method gave very concordant results. To determine the optical distance e between the plates, the diameters of the steel balls were first measured by a micrometer screw, and the mean taken. Then, after the adjustment of the apparatus, an exposure was made, and the order of the centre determined by Rayleigh's method.¹⁷ After much useless labor with Kayser and Runge's wave-lengths, corrected to the temperature and pressure of the experiment, Fabry and Perot's wave-lengths were tried: they gave the number required without much further trouble.

In the early stages of the work it was hoped that the labor of finding the order of the centre might be avoided by the following device. If θ is the angle of incidence of the light, of wave-length λ_0 in free ether, θ_1, θ_2 refer to successive rings when the vessel is evacuated, θ_1, θ_2^1 to any two successive rings when there is air between the plates, then, n_1 being a whole number, we have

$$\frac{2e}{\lambda_0} \cos \theta_1 = n_1$$

$$\frac{2e}{\lambda_0} \cos \theta_2 = n_1 - 1$$

$$\therefore \frac{e}{\lambda_0} (\theta_2^2 - \theta_1^2) = 1, \text{ neglecting } \theta^4$$

$$\text{So } \frac{e}{\lambda} (\theta_2^{1^2} - \theta_1^{1^2}) = 1$$

$$\therefore \frac{\lambda_0}{\lambda} = \frac{\theta_2^2 - \theta_1^2}{\theta_2^{1^2} - \theta_1^{1^2}}$$

¹⁷ *Phil. Mag.*, 6-11, 1906, p. 685; 15, 1908, p. 548.

and $\mu = \frac{d_2^2 - d_1^2}{d_2'^2 - d_1'^2}$ when d is the diameter of the ring on the photographic

plate $\theta = \frac{kd}{2f}$.

It was easily seen on trial that the diameters of the rings cannot be measured with sufficient accuracy for the formula to be a practical one.

The calculation was as follows:

P_0 is the order of the ring of diameter d_0 *in vacuo*

P is the order of the ring of diameter d *in air*

Then
$$\begin{cases} \frac{2e \cos \theta_0}{\lambda_0} = P_0 \\ \frac{2e \cos \theta}{\lambda} = P \equiv n + P_0 \text{ where } n \text{ is a small integer} \end{cases}$$

give $\mu = \frac{P}{P_0} \left[1 + \frac{k^2}{8f^2} (d^2 - d_0^2) \right]$, neglecting θ^4 , etc.

$$\mu = 1 + \frac{n}{P_0} + \frac{k^2(d^2 - d_0^2)}{8f^2} + \frac{n}{P_0} \frac{k^2(d^2 - d_0^2)}{8f^2} \dots \dots \dots (A)$$

for the values concerned it was found that the last term was negligible.

Only one of the half dozen spectral lines has been worked up: $\lambda = 5105.6 \text{ \AA. U.}$ for two independent sets of plates.

Plate No.	Pressure mm. Hg.	μ
<i>Cu. 6—</i>		
1.....	26.....	1.0000092
2.....	83.....	1.0000300
3.....	178.....	1.0000652
4.....	274.....	1.0000996
10.....	588.....	1.0002124
11.....	659.....	1.0002330
12.....	738.....	1.0002576
13.....	753.....	1.0002630
<i>Cu. 7—</i>		
6.....	38.....	1.0000155
7.....	112.....	1.0000381
8.....	201.....	1.0000697
9.....	280.....	1.0000991
10.....	359.....	1.0001283
11.....	436.....	1.0001575

12.....	439.....	1.0001588
13.....	518.....	1.0001878
14.....	600.....	1.0002137
15.....	675.....	1.0002511
16.....	749.5	1.0002609
17.....	756.....	1.0002659

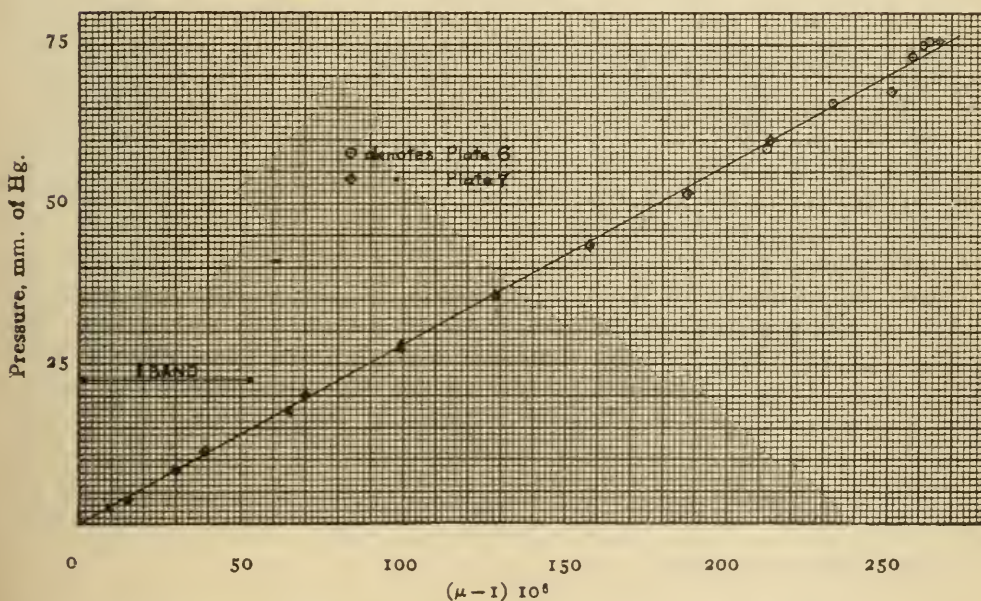
Temp. 25.9° C.

Exposures were made at lower pressures, but these were used to calculate d_0 . Equation (A) shows that, as $(\mu - 1)$ for small pressures p is proportional to p , we must have

$$\frac{\Delta d^2}{\Delta p} = \text{constant for the same ring.}$$

The results are represented graphically in Fig. 2, showing

FIG. 2.



Refractive index and pressure ($\lambda = 5105 \text{ \AA.U.}$) for air, 25.9° C.

that they are probably accurate to within $\frac{1}{20}$ of a band—which is of higher accuracy than that given by most other interference methods. The supreme advantage of the method is that the only temperature error is the alteration of the distance e ($2e = .94960 \text{ cm.}$), which at once becomes obvious by the haziness of the rings, whereas for a corresponding variation of temperature twenty or thirty bands might pass in the case of the Jamin instrument and

tubes 100 c.m. long. This method, then, could detect the difference between the laws (2) and (3) at pressures of about seven or eight atmospheres, and it is a most suitable method for different temperatures.

In conclusion, I should like to thank Dr. Barnes for his kind assistance and encouragement in the course of these experiments at Bryn Mawr College in 1910-11, as well as for the drawings of the apparatus used. Subsequently my thanks are due to the librarians of Sheffield and of Manchester Universities for their kind permission to use the libraries of the Universities.

CITY AND COUNTY SCHOOL, CHESTER, ENGLAND, December, 1913.

Practical Applications of the Gyroscope. J. AIREY (*Amer. Mach.*, xl, No. 15, 635.)—During the last decade, practically, gyroscopes have been applied with the following results: (a) The roll of a ship has been reduced, and can be reduced to any extent desired, even to zero. (b) A ship has been made to roll even though waves are absent, to enable a ship to shake herself free from ice when opening a track. (c) A ship has been made to pitch for the purpose of ice-breaking. (d) A torpedo has been forced to keep a constant direction independent of the waves tending to send it askew. (e) Platforms for quick-firing guns have been kept level in spite of the roll of the ship. (f) A one-rail train has been made a practical venture; though it remains to be seen whether it is a commercial venture on any large scale. (g) An *aéroplane* has been made automatically to keep a level deck. (h) Last, but probably most important, a compass has been made which will determine the true geographical North and thus enable navigators to be independent of the variable and troublesome magnetic North; also in the future, it will probably enable one to be independent of fine days or starry nights in accurate survey work.

Coating Iron with Aluminum ANON. (*Metal Ind.*, xii, No. 2, 77.)—A process invented by S. Uyeno, of Tokyo, coats iron with aluminum by dipping it in a bath of the molten metal after it has first been galvanized. The aluminum bath is held at the temperature of 600° to 700° C. The temporary zinc or tin surface comes away in the first dipping, but to get the best results the article to be coated is treated two or three times. The surface of the article is brushed with a steel brush during immersion. It is claimed that the aluminum coating has extraordinarily good adhesion, so that it will not peel off, and even cannot be stripped off by mechanical means. It does not tarnish under the influence of air, heat or water.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

IODINE NUMBER OF LINSEED AND PETROLEUM OILS.¹

By W. H. Smith and J. B. Tuttle.

THE Iodine Number of linseed and petroleum oils was determined according to the Hanus method. Each of the three factors, weight of sample, time of absorption, and amount of Hanus solution, was studied for a series of burnt linseed oils and petroleum oils. The results produced by variation of one of the factors, the others remaining constant, are reproduced graphically. Variations of weight of the raw linseed oil show that a constant volume is obtained for weights of the oil up to 0.25 gram. Beyond this value, the iodine number decreases with increasing weight. For burnt linseed oils, the range of weight over which the iodine value is constant decreases with increased burning of the oil. Petroleum oils, on the contrary, approach a constant value when 0.6 gram or more of the sample is taken. Varying the time of absorption from five to sixty minutes shows that the reaction approaches a maximum in about ten minutes. Thereafter, absorption is slow, and a few minutes one way or another have little effect on the value obtained. When the amount of Hanus solution is varied from 20 to 75 c.c. the results indicate that the oil with the highest iodine number does not require the greatest excess of iodine to reach maximum absorption value. The effect of temperature on the value obtained is more marked for burnt linseed oils than for boiled or raw oils. The results as a whole indicate that concordance is obtained only when a prescribed procedure is followed with exactness. To obtain comparable results, a standard procedure should be followed in which the limits are strictly defined. This is particularly true of burnt linseed oils.

* Communicated by the Bureau.

¹ Technologic paper of the Bureau of Standards, No. 37.

FLAME STANDARDS IN PHOTOMETRY.²

By E. B. Rosa and E. C. Crittenden.

ALTHOUGH an agreement has been reached regarding the relative values of the units of light in use in different countries, no one primary photometric standard has been generally adopted by the various governments. In Germany preference is given to the Hefner lamp, in England to the pentane lamp, and in France to the Carcel lamp. Each of these serves in its own country both as the primary standard and as a working standard, but for the photometry of electric lamps and generally in accurate photometric work standardized electric incandescent lamps are used in all countries. In America a group of such lamps kept at the Bureau of Standards is considered as a provisional primary standard, serving to maintain the unit until a better primary standard shall have been devised. It is believed that the unit which has been agreed upon can be so maintained with an accuracy considerably above that with which it can be reproduced by reference to any of the so-called reproducible standards at present in use. In other words, the incandescent lamps have really been employed as primary standards, and the flame standards, which logically should play the part of primary standards, have been relegated to a subordinate position.

There is, however, a possibility of an appreciable drift in the value of the unit if there is no photometric standard accurately reproducible from its specifications which is capable of serving as a reliable check upon the electric standards. It has therefore appeared worth while to make a study of the best types of flame lamps to see how closely they would reproduce in the Bureau laboratory the values adopted by international agreement and also to find whether their reliability as primary standards could be increased by any changes in construction or in operation.

The present paper discusses at length the effect of atmospheric conditions on the intensity of flames, and gives tables and curves showing the performance of typical lamps. These data are largely taken from an earlier paper (Trans. Illuminating Engineering Society, 5, p. 753, 1910).

The Carcel lamp is by far the least reliable of the three types, and cannot be considered as a competitor for general acceptance.

² Abstract of paper to be published in the Bulletin of the Bureau.

The Hefner and the pentane lamp as made at present divide honors; the latter is markedly superior as a practical standard, but individual pentane lamps do not agree, and until lamps can be independently made which shall give the same value the type can hardly be said to be reproducible. The Hefner lamp is so simple in construction that reproduction of lamps is relatively easy. Lamps now made show small differences due to slight departures from mean dimensions, but these differences can be made negligible by more careful construction. Great difficulty is experienced, however, in making accurate comparisons of working standards against Hefner lamps because of the very low intensity (0.9 candle) and the red color of the flame.

It is believed to be possible to apply the principle of the present pentane lamp in specially made, accurately specified lamps with interchangeable parts, and thus to obtain a closer agreement between lamps. Then by operating the lamps under definite conditions one should be able to obtain sufficient precision with either the Hefner or the pentane lamp to give a valuable check on the electric standards now in use.

Disappearance of two Pacific Islands. ANON. (*Sci. Amer.*, cix, No. 26, 487.)—Press reports state that Falcon and Hope Islands of the Tonga or Friendly group, in the South Pacific, have sunk in the sea, carrying with them several hundred natives and a few white men. Both were volcanic islands. Falcon Island was first seen as a breaking reef from H. M. S. "Falcon" in 1865; in 1877 smoke was seen issuing from the sea at this place; and finally, in 1885, a full grown island appeared, consisting of loose volcanic ashes. A considerable part of it was subsequently washed away by the action of the sea. It is assumed that the "Hope Island" of the newspaper report is Good Hope Island or Niuafofua, which has been the site of numerous volcanic outbreaks, entailing much loss of life and property. The Tonga Islands constitute a native kingdom under British protection.

French Mail Line by Air across the Sahara. ANON. (*Sci. Amer.*, cx, No. 3, 61.)—The National Aërial League has completed plans for the flight of a flotilla of aëroplanes across the Sahara. They will start from Oran, Algeria, and the final landing will be made at Timbuktu, French Soudan, a distance of 1400 miles. Pyramids of stones will be placed at intervals to mark the route. If the experiment proves successful the establishment of a regular air mail service will be considered.

Production of Luminescence by Kathode and Canal Rays at Liquid-air Temperature. E. OHLON. (*Ark. för Mat. Astron. och Physik.*, viii, 22.1.)—A large number of minerals and metallic salts were examined with regard to their properties of emitting luminescence under the action of kathode and canal rays. The observations with minerals were of a preliminary character only and revealed the fact that the intensity of the luminescence produced by these agencies was much greater at low than at ordinary temperatures. Therefore the observations with the metallic salts were made at the temperature of liquid air. With the salts of the more electropositive metals, viz.: Li, Na, K, Ca, Ba, Sr, and Mg, two types of luminescence are to be observed. When the salts are first subjected to the rays a bluish luminosity is seen which diminishes in intensity, in some cases rapidly, giving place to a second luminescence which varies in color according to the salt. With the salts of Zn, Cd, Pb, Hg, Fe, Cu and Mn, luminescence of the second type only is to be observed. After comparing these results with those of Goldstein and others, it is concluded that the first type of luminescence, which is similar for different substances, is caused by the escape of electrons, since it occurs with salts of the photoelectric metals; the second type is due to the escape of the metal atoms which have previously lost their valency electrons, for in some instances when canal rays are the exciting agency, the luminosity gives line spectra characteristic of the metal. However, the spectra generally consist of bands. The experimental results are given in tabular form and include observations on the phosphorescence and thermoluminescence of the substances.

Instability of Electric Circuits. C. P. STEINMETZ. (*Amer. Inst. Elect. Engin. Proc.*, xxxiii, 13.)—This gives the theory of the stability and instability of electric circuits. The types of instability are classed under three heads. There are first the transient disturbances which arise, caused by changed circuit conditions, making a readjustment of the stored energy necessary. Secondly there is unstable electrical equilibrium, where the effect of the cause increases the cause. This is illustrated by the electric arc working at constant potential and by an induction motor working on certain loads and between certain speed-ranges. In the third type there is permanent instability due to a combination of circuit constants which cannot coexist simultaneously. This is illustrated by an arc to earth on a transmission line, by the hunting of rotary converters and the phenomena of continuous and cumulative oscillations. It is proved that such phenomena require an energy supply, due to the lag of the effect behind the cause, as in a hysteresis cycle, and often involve a transformation of the frequency. As a general illustration of this type of instability the phase-swinging of synchronous machines is discussed, the mechanism of the transfer of the oscillating energy from the power supply being pointed out.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, May 20, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 20, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership, 11.

The chairman announced that the first business of the meeting would be the presentation of Elliott Cresson Medals to the distinguished scientists who had recently been recommended for this recognition by the Committee on Science and the Arts, and recognized Dr. Harry F. Keller, who then introduced Dr. Edgar Fahs Smith, of Philadelphia, Pa., and Dr. Orville Wright, of Dayton, Ohio.

The chairman presented the medal and diploma to each of these gentlemen.

Mr. Louis E. Levy was then recognized and described briefly the work of Dr. Carl Paul Gottfried Linde, of Munich, Germany, in the field of low temperature production and commercial refrigeration, and the researches of Dr. Josef Maria Eder, of Vienna, Austria, in the science of photochemistry, the foreign medalists who were unable to be present and to whom the medals would be forwarded.

Addresses were then made by the recipients of the medals, as follows:

"Scientists from the Keystone State," by Dr. Edgar Fahs Smith.

"Stability of Aeroplanes," by Dr. Orville Wright.

After a vote of thanks to the speakers the meeting adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in the July number.)

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
May 6, 1914.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 6, 1914.

MR. GEORGE R. HENDERSON *in the Chair.*

The following report was presented for final action:

No. 2585.—E. B. Ridgway's Steam Hydraulic Elevator.

Certificate of Merit. Adopted.

The following reports were presented for first reading:

No. 2588.—John V. Rice's Gasoline Rock Drills. Referred back.

No. 2593.—A. Atwater Kent's Ignition System.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, April 23, 1914, at 8 o'clock.

Mr. W. C. L. Eglin occupied the chair.

The minutes of the previous meeting were approved as published.

The chairman introduced Dr. A. E. Kennelly, Professor of Electrical Engineering, Harvard University, Cambridge, Mass., who delivered a lecture entitled "Recent Developments in Hyperbolic Functions, as Applied to Electrical Engineering." In this lecture Dr. Kennelly outlined the fundamental principles of hyperbolic trigonometry, by the use of which the properties of long alternating current lines are so greatly simplified. He described the advances made in the last two years in the applications of this branch of mathematics to the solution of electrical engineering problems. With the aid of lantern slides, he illustrated charts and tables of functions adapted to such application.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A joint meeting of the section and of the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday evening, April 30, 1914, at eight o'clock.

Mr. G. R. Henderson, President, occupied the chair.

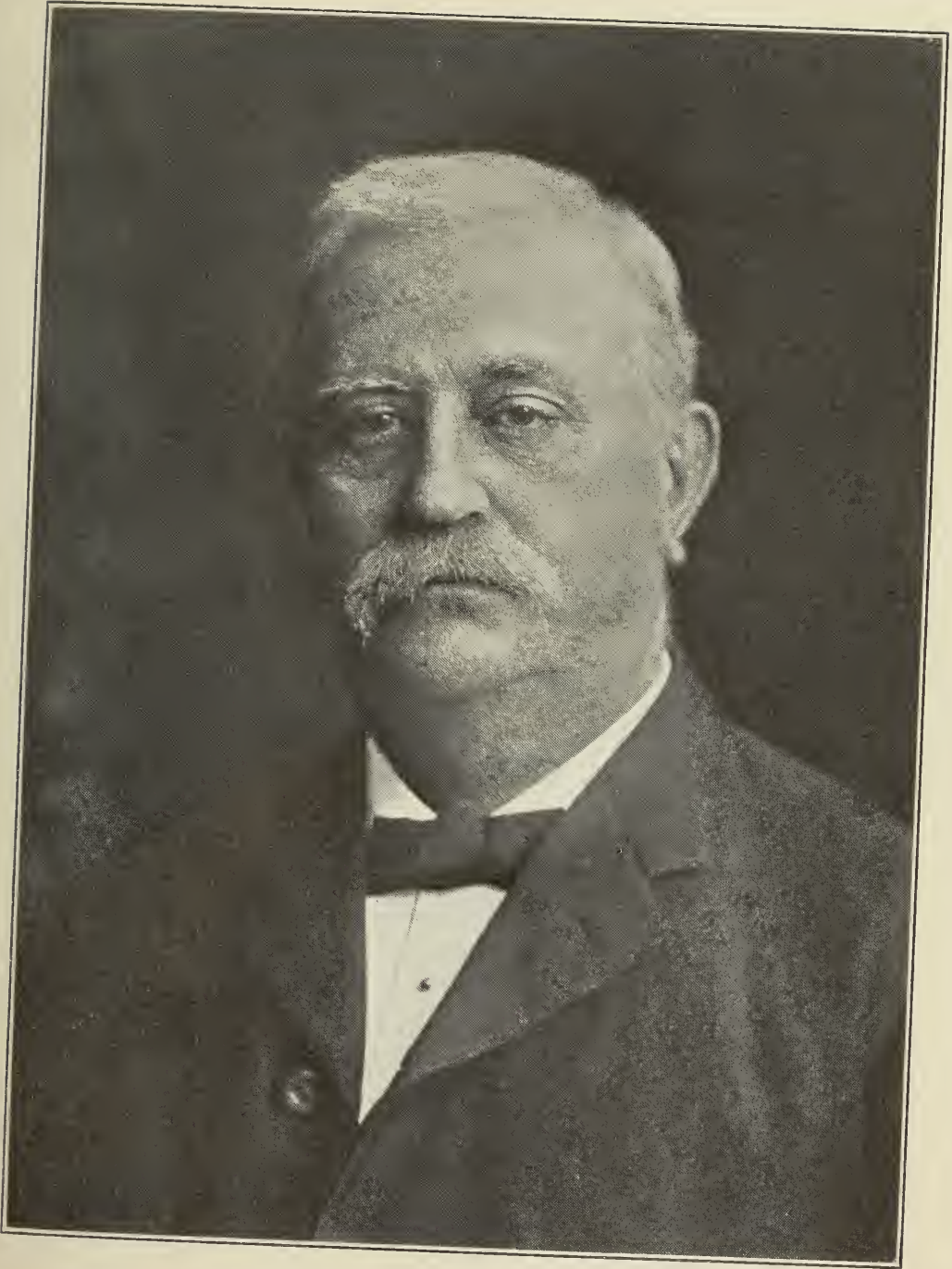
The minutes of the previous meeting were approved as published.

The chairman introduced Mr. C. D. Young, Engineer of Tests, Pennsylvania Railroad Company, Altoona, Pa., who presented a paper entitled "Locomotive Superheaters and Their Performance." The paper treated of the development of the superheater as applied to early locomotives and of its application to modern locomotives. The results obtained from exhaustive experiments at the Pennsylvania Railroad Company's Testing Plant at Altoona to determine the comparative economy of superheated and saturated steam were given. It was also indicated how these results were confirmed by actual operation on the road. The paper was well illustrated with lantern slides.

Several members present participated in the discussion, after which the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.



Alfred Noble



MEMBERSHIP NOTES.**Elections to Membership.**

(Stated Meeting, Board of Managers, May 13, 1914.)

RESIDENT.

- MR. JOHN ASHHURST, The Free Library of Philadelphia, 13th and Locust Streets, Philadelphia.
MR. THEODORE W. CRAMP, 1411 Chestnut Street, Philadelphia.
MR. J. HERON CROSMAN, JR., The Bell Telephone Company of Philadelphia, 13th and Arch Streets, Philadelphia.
MR. GEORGE W. ELKINS, Land Title Building, Philadelphia.
MR. THOMAS FISHER, 1100 Commercial Trust Building, Philadelphia.
MR. RODMAN E. GRISCOM, 231 Land Title Building, Philadelphia.
MR. PERCY C. MADEIRA, North American Building, Philadelphia.
MR. T. E. MITTEN, 1216 Bellevue Stratford Hotel, Philadelphia.
MR. J. EDWARD PATTERSON, Secretary of Arthur H. Thomas Company, 230 South Seventh Street, Philadelphia.
MR. RICHARD P. C. SANDERSON, 107 Swarthmore Avenue, Ridley Park, Pennsylvania.

NON-RESIDENT.

- MR. W. F. THORNTON, 1315 Waucoma Street, Birmingham, Alabama.

Changes of Address.

- MR. LEO D. FIRMAN, 5903 Carpenter Street, Philadelphia.
DR. EDWARD P. HYDE, Nela Park, Cleveland, Ohio.
MR. J. L. KILPATRICK, Aberdale Road, Bala, Pennsylvania.
MR. TINIUS OLSEN, Hotel Stenton, Broad and Spruce Streets, Philadelphia.
MR. ISHAM RANDOLPH, 1827 Continental and Commercial National Bank Building, Chicago, Illinois.
MR. S. N. SMITH, Montgomeryville, Pennsylvania.
MR. ORIN C. STOUT, 201 Wyandotte Building, Columbus, Ohio.

NECROLOGY.

Dr. Alfred Noble was born at Livonia, Michigan, in 1844 and was graduated from the University of Michigan in 1870. After his graduation he was for some months engaged on harbor surveys on Lakes Michigan and Huron and was then placed in charge of the improvement of the St. Mary's Falls Canal, a position which he held for twelve years. In 1882 he resigned from the government service and after serving some months as Engineer of Construction of the Red River Bridge at Shreveport, La., he was appointed General Assistant Engineer of the Northern Pacific R. R., in which position he continued for three years. From 1886 to 1894 he had special charge of

the construction of several important bridges in various sections, among them being the Bellefontaine and the Leavenworth bridges over the Mississippi. In 1895 he was appointed a civilian member of the first Nicaragua Canal Commission; the report of this Commission led to the abandonment of the Maritime Canal Company's Route. Dr. Noble was also a prominent member of the Isthmian Canal Commission of 1899, and he rendered important service as a member of the United States Deep Waterways Commission in 1897. Following his activities on these commissions, he was engaged in private practice in a number of important works. From January, 1902, to 1910, he was Chief Engineer of the East River Division of the Pennsylvania Tunnel and Terminal R. R., during the period of the construction of the four tunnels across the East River and of the Terminal Station. In 1905 Dr. Noble was appointed by President Roosevelt a member of the International Board of Consulting Engineers on the Panama Canal. From May, 1909, he was engaged in general consulting practice with the firm of Noble and Woodard, and also acted as consulting engineer to the Board of Water Supply of the City of New York.

His connection with learned societies included presidency of the American Society of Civil Engineers and of the Western Society of Engineers; it also embraced membership of the Institution of Civil Engineers of Great Britain, etc. In 1895 Dr. Noble received the honorary degree of LL.D. from Michigan University. In 1910 he was presented with the John Fritz Medal for notable achievements in civil engineering. He was awarded the Elliott Cresson Medal, the highest recognition in the gift of The Franklin Institute, in 1912, and in the following year he was elected to membership in the Institute, and was also from this time one of the associate editors of its Journal.

George E. Kirkpatrick, general manager of the Girard Estate for the Board of Directors of City Trusts of the City of Philadelphia, was born in Philadelphia in 1858. He became affiliated with the Girard Estate in 1878, soon being made superintendent, then manager, and finally general manager, which position he held at the time of his death. His father also occupied the latter position for a number of years, and was at one time a professor in the Philadelphia High School.

Mr. Kirkpatrick was for some years a director of the Commonwealth Title Insurance and Trust Company. He was a member of the Geographical Society, a director of the Wanamaker Institute of Industry, treasurer of the Alumni Society of the Central High School, and Secretary of the Girard Water Company.

He was elected to membership in The Franklin Institute in 1889, and from 1911 to his death he was a member of its Board of Managers. His connection with the Institute was chiefly in the administration of the John Scott Medal Fund, from the income of which awards and premiums are given by the Board of Directors of City Trusts on the recommendation of the Institute.



George Simpson

LIBRARY NOTES.

Purchases.

- BARKER, A. H.—Barker on heating; theory and practice of heating and ventilation. 1913.
- BLACKWOOD, WILLIAM.—Calico engraving: a practical text-book. 1913.
- BRAME, J. S. S.—Fuels—solid, liquid and gaseous. 1914.
- CROSBY and FISKE.—Handbook of fire protection. 1914.
- DICKINSON, H. W.—Robert Fulton, engineer and artist, his life and works. 1913.
- FRENCH, J. W., ed.—Modern power generators. 2 vols. 1908.
- GERLAND, ERNST.—Geschichte der Physik. 1913.
- HALL, JOHN HOWE.—The steel foundry. 1914.
- HAZEN, ALLEN.—Clean water and how to get it. 1914.
- Industrial Arts Index.—Vol. 1. 1913.
- JACKSON, WALTER.—Electric car maintenance. 1914.
- KÄHLER, KARL.—Luftelektrizität. 1913.
- London Chemical Society.—Progress of chemistry. Annual Report, vol. 10. 1913.
- U. S. War Dept., Engineer Corps.—Engineer field manual. Pts. 1-4. 1912.
- WALKER, G. W.—Modern seismology. 1913.
- WOOD, JOHN K.—Chemistry of dyeing. 1913.
- WREN, HENRY.—Organometallic compounds of zinc and magnesium. 1913.

Gifts.

- American Gas Institute, Proceedings, vol. 8, 1913. New York, 1914. (From the Institute.)
- American Institute of Electrical Engineers, Transactions, vols. 28-31, 1909-1912. New York, 1909-1912. (From Dr. R. B. Owens.)
- American Mining Congress, Report of Proceedings, 1913. Denver, 1914. (From the Congress.)
- Baldwin Locomotive Works, Record No. 76. Philadelphia, 1913. (From the Works.)
- Bowser, S. F. & Co., Oil Filtration. Fort Wayne, Ind., no date. (From the Company.)
- Brooklyn Institute of Arts and Sciences, 23rd to 25th Year-book, 1910-1912. Brooklyn, 1910-1912. (From the Institute.)
- Canada Board of Railway Commissioners, 8th annual report, 1913. Ottawa, 1914. (From the Commissioners.)
- Cause of business depressions, by Hugo Bilgram and Louis Edward Levy. Philadelphia, 1914. (From the Authors.)
- Chart Atlas of Complex Hyperbolic and Circular Functions, by A. E. Kennelly. Cambridge, 1914. (From the Author.)
- Concord Water Department, 42nd Annual Report. Concord, N. H., 1914. (From the Department.)
- Connecticut Public Utilities Commission, 2nd Annual Report, 1913. Hartford, 1914. (From the Commission.)

- Elements of trigonometry, by Herbert C. Whitaker. New York, 1898. (From the Author.)
- Finland Patent Office, Arbetsstatistik XVI, Undersökning angående Sägindustri. Helsingfors, 1914. (From the Office.)
- George Washington University, Catalogue, March, 1914. Washington, D. C., 1914. (From the University.)
- Kolonial Instituut, Derde Jaarverslag, 1913. Amsterdam, no date. (From the Institute.)
- Michigan State Board of Health, 40th Annual Report, 1912. Lansing, 1914. (From the Board.)
- National Association of Cotton Manufacturers, Transactions No. 95. Boston, 1914. (From the Association.)
- New Bedford Water Board, Report, 1913. New Bedford, Mass., 1914. (From the Board.)
- New York Central and Hudson River Railroad Co., Report for 1913. New York, no date. (From the Company.)
- New York City Public Service Commission for the First District, Regulation of Public Service Companies in Great Britain. New York, 1914. (From the Commission.)
- Oberlin College, Annual Catalogue, 1913-14. Oberlin, Ohio, 1914. (From the College.)
- Ontario Department of Agriculture Entomological Society, 44th Annual Report; Fruit Growers' Association, 45th Annual Report; Horticultural Societies, 8th Annual Report. Toronto, 1914. (From the Department.)
- Pennsylvania Department of Fisheries Report, 1912; Sinking Fund Commissioners Report, 1913; Secretary of Internal Affairs, Part 3, Report, 1912; and Department of Mines, Part 2, Report, 1912. Harrisburg, 1914. (From the State Librarian.)
- Pennsylvania Railroad Company, 67th Annual Report, 1913, and 59th Annual Report of The Northern Central Railway Co. Philadelphia, 1914. (From the Company.)
- Pennsylvania State Librarian, Report of Librarian, 1913. Harrisburg, 1914. (From the Librarian.)
- Philadelphia Civil Service Commission, Annual Report, 1906-1912. Philadelphia, 1906-1912. (From the Commission.)
- Providence Public Library, 36th Annual Report, 1913. Providence, Rhode Island, 1914. (From the Library.)
- Railway Statistics of the United States for 1913. Chicago, 1914. (From Mr. Slason Thompson.)
- Society for the Promotion of Engineering Education, Proceedings, 1910-1912. Ithaca, N. Y., 1911-1913. (From Dr. R. B. Owens.)
- Study of North Appalachian Indian Pottery, by Christopher Wren. Wilkes-Barre, Pa., 1914. (From the Author.)
- United States National Museum, Annual Report, 1913. Washington, D. C., 1914. (From the Museum.)
- University of Colorado, Catalogue, 1913-1914. Boulder, 1914. (From the University.)

- University of South Carolina, Catalogue, 1913-1914. Columbia, 1914. (From the University.)
- Verein deutscher Eisenhüttenleute. Mitgliederverzeichnis, 1914. Düsseldorf, 1914. (From the Society.)
- Wilmington Board of Park Commissioners, Report, 1913. Wilmington, Del., no date. (From the Commissioners.)
- Wisconsin History Commission, Original Papers, No. 8. Madison. 1914. (From the Commission.)
- Zeitschrift des Vereins der Deutschen Zucker-Industrie, General-Register, 1893-1912. Berlin, no date. (From the Society.)
- Zoological Society, The Forty-second Annual Report. Philadelphia, 1914. (From the Society.)
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BOOK NOTICES.

THE GAS LIGHT & COKE COMPANY, 1812-1912. An account of the progress of the Company from its incorporation by Royal Charter in the year 1812, to the present time. Published privately.

This attractive brochure of 92 pages, with 42 illustrations, constitutes a most important contribution to the history of Public Service corporations and to the history of the gas industry. Written in pleasing style, it describes the conditions existing in London when this first gas company was projected; reviews the early experiments in gas transmission; the propaganda for and birth of the Company; the criticisms, obstacles and misfortunes it encountered and surmounted; its absorption of rival companies which had been created because of its own pioneering work; the development at Beckton of the enormous factory wherein the by-products are remanufactured into a large variety of much sought products; and beginning so far back as 1841, the sharing of the profits with the employees, first by superannuation and sick funds and later by copartnership. It is a history which no student of economics, sociology, politics or industry can afford to remain unacquainted with. The statistics are most impressive, for in 1911 this single city gas company had a capital of nearly \$145,000,000, employed 12,637 workmen, and sold over 25,000,000 thousand cubic feet of gas, while it collected from its automatic meters 231,736,536 pennies. Beginning with gas at \$3.64 per thousand it was five years before a dividend was paid. Under the London Sliding Scale it sold gas in 1912 for 60 cents per thousand and made a handsome profit.

The centenary which this brochure celebrates has a special interest for the readers of this Journal and the members of the Institute. The origin of the celebration, held so successfully at the Institute on April 18th and 19th of 1912, is set forth in full by Walton Forstall in this Journal on page 627 for June, 1912, and this convocation led to the publication by the American Gas Institute of the volume of 174 pages entitled "Lectures delivered at the Centenary Celebration of the First Commercial Gas Company to sell Gas as an Illuminant." Many centenary celebrations were

also held by the several local sections of the American Chemical Society and by various organizations devoted to the gas industry. The *Illustrierte Zeitung* of Leipzig brought out its number for June 27, 1912, as *Technische Kulturbilder I: Gas-Jahrhundert-Nummer* with a 110-page supplement filled with illustrations, many of which are in color. And now, to complete the record, comes this brochure.

CHARLES E. MUNROE.

PUBLICATIONS RECEIVED.

Practical Iron Founding, by Joseph G. Horner. Fourth edition, thoroughly revised and enlarged. 409 pages, illustrations, plates, 12mo. London, Whittaker & Co., 1914. Price, 5 shillings.

The Synthetic Use of Metals in Organic Chemistry, by Arthur J. Hale. 169 pages, 12mo. Philadelphia, P. Blakiston's Son & Co., 1914. Price, \$1.50.

Modern Steel Analysis. A selection of practical methods for the chemical analysis of steel, by J. A. Pickard. 128 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1914. Price, \$1.25.

The Theory of Heat Radiation, by Dr. Max Planck. Authorized translation by Morton Masius. 225 pages, 12mo. Philadelphia, P. Blakiston's Son & Co., no date. Price, \$2.00.

Biochemic Drug Assay Methods, with Special Reference to the Pharmacodynamic Standardization of Drugs, by Paul S. Pittenger. Edited by F. E. Stewart. 158 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., no date. Price, \$1.50.

U. S. Bureau of Mines, Bulletin 67. Electric Furnaces for Making Iron and Steel, by Dorsey A. Lyon and Robert M. Keeney. 142 pages, illustrations, 8vo.

Technical Paper 68, Petroleum technology 15. Drilling Wells in Oklahoma by the Mud-laden Fluid Method, by A. G. Heggam and J. A. Pollard. 27 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

U. S. Department of Agriculture, Bulletin No. 93: The Temperature of the Honeybee Cluster in Winter, by E. F. Phillips, Ph.D. 16 pages, 8vo. Bulletin No. 103: Alum in Foods. 7 pages, 8vo. Bulletin 583: The Common Mole of the Eastern United States, by Theo. H. Scheffer. 10 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

Konstant auftretende sekundäre Maxima und Minima in dem jährlichen Verlauf der meteorologischen Erscheinungen von Dr. E. van Rijckevorsel. Xter Teil. Separat Abzug aus: Koninklijk Nederlandsch Meteorologisch Instituut, No. 102. 23 pages, tables, plates, 8vo. Utrecht, Kemink & Zoon, 1914.

Eli Whitney Blake, Scientist and Inventor, by Henry T. Blake. 19 pages, portrait, 8vo. No place, no date.

The Engineers' Club of Dayton, General information, by-laws. 28 pages, 12mo. Dayton, Ohio, 1914.

National Association of Cotton Manufacturers, Programme and Papers; Annual Meeting, Boston, Mass., April 29 and 30, 1914. 17 pamphlets, 8vo. Boston, Association, 1914.

CURRENT TOPICS

Increasing Size of Steam Turbines. ANON. (*Sci. Amer.*, cx, No. 8, 155.)—An extraordinary development is taking place in the size of the individual unit in the field of steam turbines. A short time ago the *Scientific American* commented on the fact that a unit of 20,000 kilowatts had been built; yet during the past year one of this size and another turbine of 25,000 kilowatts have been constructed. It is stated that orders have been placed for four of 30,000 kilowatts and one of 35,000 kilowatts.

Linking Germany with her Colonies. ANON. (*Sci. Amer.*, cx, No. 12, 245.)—The German government is negotiating with Holland for permission to erect a wireless station on the island of Sumatra, Dutch East Indies. Such a station would be able to communicate on the one side with German East Africa and on the other with the Caroline Islands. If this plan succeeds, all the German colonies would be able to communicate with Berlin without making use of any cable. This would alleviate one of Germany's greatest grievances—that in communication with its colonies it is now dependent on Great Britain, which controls most of the cables.

Spring Suspension of Cycle-cars. ANON. (*Sci. Amer.* cx, No. 6, 113.)—Because of their light weight and narrow tread, the spring suspension of cycle-cars is a matter of the gravest importance. In this connection it is interesting to note that several engineers prominent in the automobile industry have offered their opinion that the cantilever type of spring seems best adapted for these light vehicles. This type possesses two cardinal advantages: It is less expensive to manufacture than many other types and in action eliminates practically all of the uncomfortable and often dangerous rebound that is a feature of nearly all other springs.

Surface Combustion. W. A. BONE. (*J. Gas Lighting*, cxxv, 572.)—Tests made with the 110-tube boiler at the Skinningrove iron works, after 5 months' run, showed that with a total evaporation of 5000 lbs. of water from and at 100° C. per hour the ratio of heat utilized to net heat supplied was 0.927:1, and that the physical properties of the tubes were not in any way impaired. In a test of a "Bonecourt" boiler recently installed in connection with Krupp's coking plant in the Ruhr district, Westphalia, an evaporation of 6750 lbs. of water per hour from and at 100° C. with an efficiency

ratio of 0.925 was realized. In regard to surface combustion in a bed of granular refractory material for melting metals, etc., it is stated that without regeneration it should be possible to obtain easily temperatures up to 2000° C. with coal gas, coke oven gas, or water gas, or about 1500° C. with low grade producer gas, such as Mond gas. Heating by means of diaphragms has been employed for more than a year for boiling and concentrating sugar solutions in a confectionery factory, the boiling being done in a copper pan over a circular diaphragm of 13 inches diameter. Some of the diaphragms have been in continuous day use for about one year, and the gas consumption is stated to be about one-half of that required when ordinary flame burners were used. Very rapid and efficient evaporation of liquids can be effected by using overhead diaphragms.

Use of Tar in the Basic Linings of Steel Furnaces. J. WAGNER. (*Rev. Mét.*, xi, 211.)—The constituents of coal tar which are beneficial in preparing furnace hearths of dolomite and tar are coal-tar acids, anthracene oils, and non-volatile pitch. The prejudicial constituents are light oils, naphthalene, free carbon in too high a proportion, and coal-tar bases. Tar intended for this purpose should yield, on fractionation, not more than 8 per cent. below 230° C., and not less than 30 per cent. between 230° C. and 350° C., and the loss on distillation should be about 3 per cent.

Metallurgical Industry in Russia. ANON. (*Amer. Mach.*, xl, No. 14, 588.)—The metallurgical industry of Russia, the principal centre of which is in Odessa, is showing increasing activity. Whether it will be able to cope with the growing demand for iron and steel is doubtful. In 1913 the production of pig iron amounted to 4,660,000 tons as against 3,500,000 in 1911. About 50,000 tons were imported; none was exported. The chief coal producing centre of Russia is in the Donetz basin, which provides 55 per cent. of the coal consumed in the country. Its output has risen from 12,000,000 tons in 1900 to 28,000,000 in 1913.

Magnalium for Pistons. ANON. (*Metal Ind.*, xii, No. 3, 104.)—Emil Grossman, a manufacturer of spark plugs, states that magnalium, an alloy of aluminum and magnesium, considerably lighter than aluminum, which has been used successfully for cylinders of gas engines, is now being tried for the manufacture of pistons for automobiles. For the past few years automobile engineers and designers have been giving a great deal of attention to the reduction of the weight of the various functioning parts of the gasoline motor. Ordinary cast iron used has a tensile strength of from 18,000 to 20,000 pounds per square inch, with a specific gravity of 7.5; while magnalium is stated to have a tensile strength of 23,000 pounds to the square inch, with a specific gravity only 2.5.

Absorption of Gases by Coal.—F. LEPRINCE-RINGUET. (*Comptes Rendus*, clviii, 573.)—Such gases as fire-damp, carbon dioxide, air, oxygen and methane, at pressures ranging from 0.25 to 80 atmospheres, were absorbed by coal to a much less extent than by charcoal, but in both cases the absorption was of the same general character; a state of equilibrium existed for each temperature and pressure, and the absorption markedly decreased as the temperature rose; the increased absorption with increased pressure was rapid at first but gradually tended to a limit. Equilibrium was reached very slowly, and in the case of carbon dioxide especially, evolution of the absorbed gas, however slowly effected, was spasmodic. Results of the same order of magnitude were obtained with coals of widely different composition and size of grain; they afforded no explanation of the large evolution of fire-damp observed in very gassy mines.

Active Nitrogen. E. TIEDE and E. DOMCKE. (*Ber.*, xlvii, 420.)—By means of a jointless glass apparatus in which Lindes' commercial nitrogen was passed over copper heated electrically to a temperature measured by a thermo-couple, it was shown that the after-glow was suppressed unless the nitrogen was purposely contaminated with oxygen, provided that the temperature and pressure were such that no dissociation of copper oxide took place. On raising the temperature beyond a limit depending on the pressure, the glow was restored. The phosphorescence of sulphur, iodine, sodium and thallium chloride, observed on heating them in nitrogen which has been subjected to the action of the electric discharge, and attributed by Strutt to the presence of active nitrogen, was similarly suppressed in the absence of oxygen.

The Commercial Importance of Esparto Grass. C. J. KOCH. (*Tropenpflanzer*, xviii, 59.)—The esparto plant grows best on mixed limestone and gravel soils; its natural region lies between 32° and 41° N. latitude, but it is capable of resisting considerable variations in temperature and is found at altitudes up to 3000 feet. The leaf ranges in length from 30 to 70 cm., attaining 1 m. under exceptional circumstances. It is pale green while growing but becomes yellow on drying; it rolls up when drying, attaining its cylindrical form at the ripening stage. About 200,000 tons of the grass are imported almost wholly by England; the quantity has remained stationary for 15 years, a decline from one source being balanced by increased importations from other sources. If the leaf is harvested before maturity the quality of the fibre is very inferior, yielding a semi-transparent paper. In most districts the use of the knife is forbidden; a tuft of grass requires 8 to 15 years before it becomes productive and may then be "pulled" annually for 30 to 50 years. The best time for pulling is the autumn; in most countries a close season is fixed by regulation during the earlier months of the year. The

harvested grass is stored and dried for a considerable time before packing for shipment; the hydraulic pressed bales weigh about $22\frac{1}{2}$ lbs. per cubic foot. The majority of German paper makers are not interested in the grass, partly through unfamiliarity, partly owing to difficulties in procuring freights. Freights from Algiers and Oran run about 28/- per ton for Hamburg and 24/- for English ports. The area under esparto in Algeria is about 2,800,000 acres, of which three-fourths are in the department of Oran. Regulations as to season of cropping are in force, also certain zones are reserved as a protection against sand-drifts. Exports from Algeria were 100,788 tons in 1911 and 116,632 tons in 1912, average price 52/- per ton; exports from Tunisia were 50,197 tons in 1911, average price 57/- per ton. Increases from these countries in recent years have taken place at the expense of the Tripoli trade, now practically ruined by war and the scarcity of labor. The Spanish variety of esparto is still the most valuable, although high prices and careless industrial habits have led to wasteful methods of cropping. Exports have declined from about 60,000 tons in 1897 to 41,000 in 1912, but the fluctuations since 1904 show a fairly steady average; the price runs about 95/- per ton and has fallen from more than double this figure since 1883.

The Action of Formaldehyde on Wool. A. KANN. (*Färber-Zeit.*, xxv, 73.)—When treated with a 4 per cent. solution of formaldehyde wool becomes resistant to the action of alkali and loses its affinity for dye-stuffs. By the use of very weak formaldehyde solutions, 0.25 or as low as 0.1 per cent., the wool can be protected against the tendering action of alkali without losing its affinity for dye-stuffs. The reaction between wool and formaldehyde takes place with great ease in slightly alkaline solution and much less advantageously in acid or neutral solution. Wool thus treated can be dyed with sulphide dye-stuffs, it shrinks less on steaming and it can be scoured with caustic alkali, using very little soap. The treated wool reacts with nitrous acid just like untreated wool. This shows that wool does not contain an amino group, for such a group would have been rendered inactive by the formaldehyde. It is concluded that wool contains the imino group and the product of reaction with nitrous acid is a nitrosamine.

Grand Trunk-Pacific Railway nearing Completion. ANON. (*Sci. Amer.*, cix, No. 26, 487.)—This railway, which will give a new continuous route from the Atlantic to the Pacific, through Canada, has been so far completed that there remains only a gap of 220 miles to be built between Winnipeg and the Pacific Coast. On the mountain section over 600 miles of track have been completed, and the consulting engineer for the government states that as labor is abundant, the line will in all probability be finished by June 1, 1914.

Explosions in Liquid Air Plants. W. BRAMKAMP. (*Chem. Ind.*, xxxvii, 81.)—Two out of three explosions in plants for the fractional separation of oxygen from nitrogen were due to the unauthorized attempt to remove ice from the fractionating column by means of a blast-lamp and a red-hot spanner, respectively, the cork or silk lagging, saturated with oxygen, burned explosively. The third was ascribed to an accumulation in the receiver of the oxygen fraction of acetylene, partly as copper acetylide, which had escaped from a neighboring works. The author suggests as possible causes of explosions: stoppage of the tubes by solid argon; explosive vaporization of solid argon on warming; or accumulation of lubricant, or its decomposition products, or even methane from the air, which might become ignited on contact with ozone produced by the electrification by friction of the non-conducting liquid oxygen.

The Zeppelin Passenger Airship "Sachsen." ANON. (*Motorwagen*, xvi, 920.)—Aërial passenger service given by suitable airships is profitable providing a sufficient number of passengers are available. The Zeppelin Company alone has up to the present attained marked success in this field, chiefly owing to the large passenger accommodation of their vessels. The construction of the "Sachsen" is described and illustrated by half-tone; this is the 17th and latest vessel built at Frederickshaven on the Zeppelin rigid system. The "Sachsen" is 142 m. overall, 14.9 m. in diameter and 19,700 cubic metres in capacity. Eighteen gas cells in the balloon are separated by aluminum partitions; one or more cells may be emptied completely without compelling the descent of the vessel. The skeleton is covered with impregnated cotton material to reduce air resistance and the effect of the sun's rays, while making the whole fabric weatherproof. Below the balloon are suspended the two machine gondolas and the passenger cabin is between them. One 185-horsepower Maybach motor is placed in the fore, and two similar motors are placed in the aft gondola. Steering, ballast, and valve controls are assembled in the front gondola, from which the vessel is navigated. The fore motor drives a twin-blade propeller at 530 revolutions per minute. The stern motors each drive a 4-blade propeller at the same speed. The elevating and steering rudders are mounted in a common framework at the stern of the ship. Six vertical rudders enable the vessel to be turned on a radius of 350 m. Large horizontal fins extending above the rudder frame reduce any tendency to rolling to a minimum. A new feature is the addition of supplementary stabilizing surfaces, extending from the hull through the propeller frames at about 45° to the horizontal; these frames are designed to prevent the formation of eddy currents by the propellers. The multiplication of the driving and controlling equipments makes it possible to proceed after any breakdown at all likely to occur to any component of the equipment. Two motors drive the vessel at

65 km. per hour, and three motors drive it at 75 km. per hour (in still air). The gross lifting power of the "Sachsen" is 23,000 kg. at sea-level; the net or effective lifting power is about 6000 kg., according to altitude and temperature. The lifting power is reduced about 200 kg. per 80 m. of altitude and about 80 kg. per 1° C. rise in atmospheric temperature. From 1200 to 1500 kg. of oil and petrol are generally carried; this suffices for 10 or 12 hours' cruising under full power or 15 to 20 hours' cruising with two motors working. The distances traversed through the air are about 800 and 1000 km. respectively, but according to the direction of the wind, the distance travelled with regard to land or sea varies from 400 to 1500 km. A crew of nine is divided between the fore and aft machine rooms; the central cabin accommodates 25 persons and is luxuriously padded. A wireless equipment is carried. From May 3 to Sept. 30, 1913 (150 days) the "Sachsen" made on 110 days, 170 journeys, occupying 327 hours 30 minutes and totalling 15,584 km. (1600 miles). On these journeys, 3983 persons were carried at a fare usually between 100 and 200 marks each.

Algin. ANON. (*Sci. Amer.*, cx, No. 3, 61.)—A new product of seaweed is announced from Liverpool, called algin, which is used in the manufacture of non-inflammable cinematograph films and in the treatment of paper to make it water, flame and germ proof. Algin is said to be odorless.

Surveying with an Auto Truck. A party for the determination of the astronomic latitude of triangulation stations established by the Coast and Geodetic Survey and the United States Geological Survey, between Barstow, Texas, and the Pacific Ocean, has recently been formed under the direction of Mr. C. V. Hodgson, of the Coast and Geodetic Survey. Many of the stations are on mountains at an altitude of 10,000 feet and the results obtained will be used principally for geodetic purposes in the determination of the figure of the earth and the distribution of material in the earth's crust.

The means of transportation will be a $1\frac{1}{2}$ -ton automobile truck which was used successfully on similar work between Denver, Colo., and the Canadian border in the season of 1913. A similar truck had been employed also in 1912 on the 49th parallel boundary survey between the United States and Canada. The cost of the work during the season of 1913 is estimated as only one-half what it would have been if horses and wagons had been used for transportation. The saving in the coming season is expected to be even greater, as the country to be traversed is arid or semi-arid and the transportation of water and forage for stock would have been a difficult problem. It is expected that the work will continue until late in the autumn.

The conditions in which the truck was used were such as to require very frequent transportation of men and material between

widely separated points, and in a region remote from the ordinary means of communication.

In the experience with the truck in the year 1912 it was found that a field party and its equipment could cover easily from 75 to 100 miles in a day, over indifferent roads, including stops for gasoline, supplies, etc., *en route*. The machine will do the work of four horses and in one-fourth the time. It is equipped with solid rubber tires, dual behind, and with extra tanks for gasoline and water. The weight of the truck is about 6100 pounds and the weight of the equipment of all kinds carried, but excluding the weight of the three passengers, is about 2000 pounds, thus bringing the weight of the entire outfit to more than four tons. On the average, one gallon of gasoline was used for every 5.2 miles, and one gallon of oil for every 61 miles.

The chief limitation in the use of the truck for surveying arises from its weight, and a lighter truck would answer in some classes of work. Green poles were carried to place in front of the dual-tired rear wheels in passing through deep sand or mud, and heavy planks were carried for reinforcing the flooring of weak bridges. For use in mud or sand the dual tire possesses a great advantage over the single tire, but on the deeply rutted prairie roads the duals were found to wedge and bind in the ruts, so that it was necessary to take to the prairie alongside the road. For a skid chain a heavy, close-linked rather flat chain about 17 feet long was used. This was wound about six times around the rim and tires of each rear wheel and the ends fastened by heavy buckled straps by which the slack could be taken up.

Lead and Aluminum. ANON. (*Brass World*, x, 3, 84.)—Lead and aluminum do not alloy; if the two metals are melted together they separate upon cooling. At the bottom of the crucible lies the lead containing a trace of aluminum, and at the top lies the aluminum containing a very small amount of lead. The two metals adhere to one another when they have cooled and set, but with a distinct line of separation.

Instability of Gaseous Ions. R. D. KLEEMAN. (*Cambridge Phil. Soc. Proc.*, xvii, 263.)—The previously attained results are summarized, and then the results of further experiments are discussed, leading to these conclusions: (1) The period of life of an elementary ion or cluster varies largely with the nature of the gas, and is greatly modified by slight admixtures of other gases; (2) the period of life of a cluster in a gas at standard pressure may have a value lying between a few seconds and a small fraction of a second. The order of magnitude of the period of life of an elementary negative ion is about 1/100 that of a cluster. The various expressions obtained by physicists for the velocity of an ion through a gas, on the assumption

that it consists of an unchanging cluster of molecules, must therefore be regarded as merely useful empirical formulæ. The results also suggest a modification in the ordinary theory of ionisation by collision, as they indicate, not a current of elementary ions only, but also a current of clusters. The velocity of atomic ejection of an electron can have but little influence on the resulting ionisation by collision, as the electron will, on an average, undergo hundreds of collisions before reaching an electrode. But the direction of ejection relatively to that of the electric field will greatly affect the formation of clusters. A formula is developed for calculating the life period of a positive cluster, but the absence of data precludes the deduction of any definite conclusions from it, or even as to the life period of an elementary positive ion.

Plant for Producing Calcium Carbide and Nitrate. ANON. (*Sci. Amer.*, cx, No. 3, 61.)—An electro-chemical works, which ranks among the large Swedish plants of that type, has been installed near Johannesburg and is designed to turn out calcium carbide and nitrate by a new process invented by Engineer F. Carlson. It is stated that there are now running on this principle four 400-kilowatt furnaces using single-phase current, for the production of carbide. As to calcium nitrate, used as a fertilizer, there are six furnaces in use on the 3-phase system of 2600-kilowatt size. To secure the current the present plant demands, a large hydraulic plant is erected that cost over a million dollars and operates by power from the Ljungan stream.

Electric Conditions for the Change from the Arc- to the Spark-spectrum. P. LUDEWIG. (*Ann. d. Physik.*, xlii, 3, 643.)—La Rosa has shown that in the light from the singing arc there is a change from the arc- to the spark-spectrum according to the relative magnitudes of the self-induction and capacity in the oscillating circuit. Wagner has investigated the subject further. The research shows that the spark-spectrum is not necessarily associated with the existence either of a high-potential or of electric oscillations. The spark-spectrum arises when the current curve consists of sudden jumps, with sufficiently long pauses lying between. The duration of the impulsive currents must be smaller than 10^{-4} second. Between the spark-spectrum and the arc-spectrum there exists a continuous series of intermediate spectra, and by increasing the duration of the current impulses the spectrum approaches nearer and nearer to the arc-spectrum. It thus appears that the arc- and spark-spectra take a special place in this series of spectra only because they happen to be, so far as is now known, the end members of the series. It is quite possible the series of spectra may be extended.

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No. 1

LOCOMOTIVE SUPERHEATERS AND THEIR
PERFORMANCE.*

BY

C. D. YOUNG,

Engineer of Tests, The Pennsylvania Railroad Company, Altoona, Pa.,
Member of the Institute.

PART I.

AN interest in the subject of superheaters, which has continued for over two centuries, and has culminated at the present day in their almost universal application to steam locomotives, can be shown to have been fully justified by the substantial economies now derived from the use of superheated steam.

It will be my purpose to trace first the history and development of locomotive superheaters, and then to show, from tests, some of the effects of superheating, and the advantages of its use in a large passenger locomotive.

Superheating, or what in the early days was termed "overheating" of steam, has been used and studied since the earliest inception of the use of the expansive force of steam, because we find that Dionigi Papin, as early as 1705, superheated steam by means of a red-hot bar placed in the cylinder itself, and he describes the process as "the steam receiving greater expansion than in the boiler."

Henry Wood in 1759, Joseph Hatley in 1768, Thomas Mead

* Presented at the meeting of the Mechanical and Engineering Section, Thursday, April 30, 1914.

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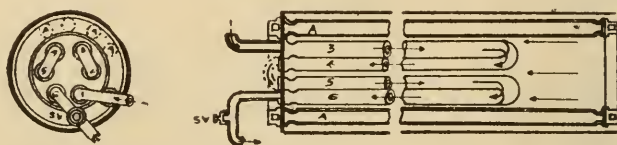
I

in 1791 and Arthur Woolf in 1804 made studies of devices involving the use of superheated steam. It was not, however, until 1832 that the inventor and constructor of the first steam locomotive, Richard Trevithick, made a practical application to a locomotive. His superheater is shown in Fig. 1. In his patent, No. 6308, 1832, he describes his method of superheating as:

"The interposition between the boiler and the cylinder of a long pipe heated and curved in the form of a buckle through which the steam is obliged to pass with great rapidity and without ever entering into contact with the water."

This figure illustrates, as far as the author's knowledge goes, the first conception of a superheater of the general form now in use, and it is noteworthy that the design embodied some of the essential features of modern practice, as will be pointed out later when tracing out the development of the various forms of superheaters.

FIG. 1.



TREVITHICK'S SUPERHEATER, 1832, FIRE TUBE TYPE.

The first design of a locomotive superheater. The superheating element, consisting of a return tube inserted in the fire tube of the boiler, is essentially the same as that used to-day.

While the invention and development of superheaters as applied to locomotives have been principally along four general lines, it is of considerable interest to observe, as well, that but one type has come into popular favor and wide use, and this is the fire tube type.

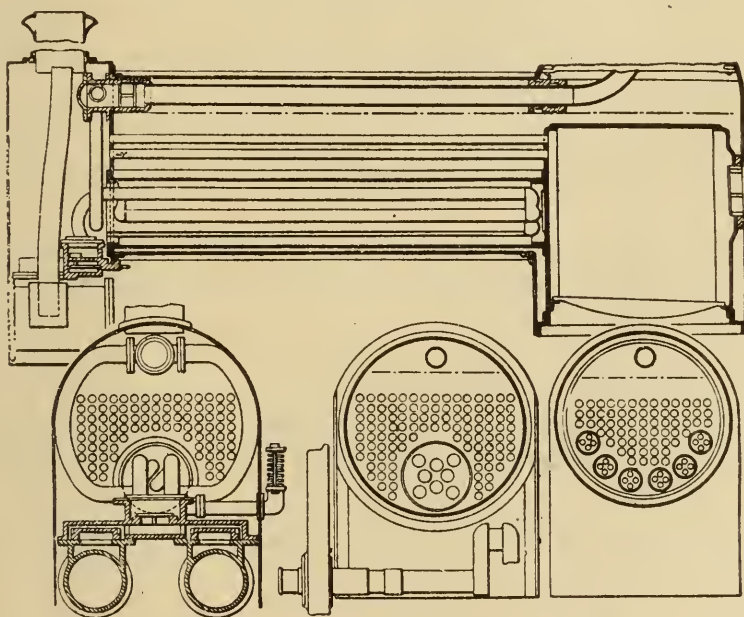
In the arrangement for this method of superheating, as in the case of Trevithick's invention, 1832, the steam, after leaving that portion of the boiler in which it is generated, is passed through either straight or bent pipes, located in one or more enlarged fire tubes of the boiler, the pipes for conveying and superheating the steam extending to a point as close to the furnace fire as is permissible by the tube arrangement of the boiler.

A second form which received some attention in the early application to locomotives is known as the smokebox type, and in this an attempt was made to utilize, for superheating, some

of the waste heat of the gases of combustion after they had passed out of the boiler tubes proper. This design has attracted special attention, for the reason that the superheating was accomplished by a utilization of what otherwise would be wasted heat and because it furnished a superheat of low temperature, and thus avoided trouble with cylinder packing and lubrication.

A third arrangement, where the superheater occupies a portion of the barrel of the boiler and uses part of the length of the fire tubes for superheating, has never had extensive application, although it has appeared from time to time in the construction of locomotives, both in this country and abroad. Its advocates

FIG. 2.



DE MONTCHEUIL'S SUPERHEATER, 1850, FIRE TUBE TYPE.

Three possible arrangements of the elements in the fire tube are shown

were apparently seeking an intermediate temperature of superheat, higher than that which could be provided by the waste heat superheater, but at the same time they did not care to utilize the high temperature of steam produced by the fire tube type, the first mentioned.

A fourth method, viz., furnace or firebox type, in which the tubes containing the steam to be superheated are placed immediately in contact with the fire, has been devised within the last thirty years. By such an arrangement it is possible to obtain the highest degree of superheat with the least area of heating surface. This construction has met with very little success,

probably due to the fact that means have not been provided to take care of the high temperature to which the steam tubes are subjected. The possibilities of this and the other constructions will be touched upon in discussing the details of each of the types mentioned.

The fire tube superheater is the simplest form, and the earliest arrangement of it is shown in Fig. 1. The construction of Trevithick was made applicable to a locomotive by De Montcheuil in 1850 (see Fig. 2, which shows De Montcheuil application to a locomotive of the Montereau & Troyes Railway). His construction, somewhat modified, is used to-day in the application of superheaters to modern locomotives. Designs based on this arrangement furnish a superheat as high as 300 degrees with a boiler pressure of 200 pounds per square inch, corresponding to a temperature of the steam of 690° F.

The devices, in the order of their importance so far as their application to locomotives is concerned, are again outlined as follows:

1. The fire tube type, in which separate superheater elements are placed inside of special fire tubes provided for their reception.
2. The smokebox type, in which the entire superheater, or a portion of it, is located in the smokebox.
3. The boiler barrel type, in which a portion of the heating surface of the fire tubes of the boiler is used for superheating the steam.
4. The firebox and flue type, in which a portion, or the entire superheater heating surface, is placed in the firebox.

Whether to class a superheater as of the barrel or of the smokebox type is often a question, particularly when the water-heating surface is encroached upon to permit of a large area of superheating surface.

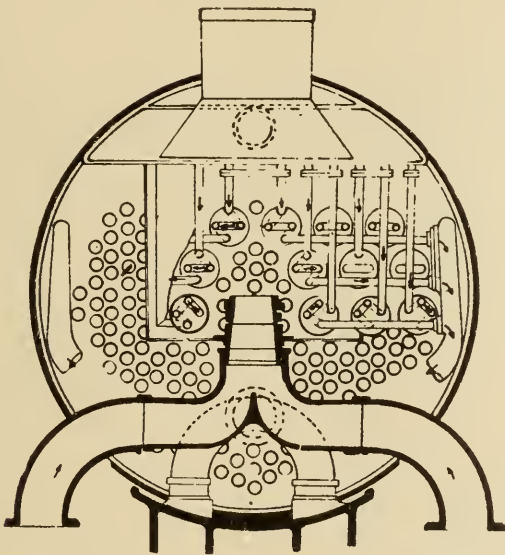
The various superheaters will now be discussed in greater detail with typical illustrations under each classification.

FIRE TUBE TYPE.

The superheater now in most general use is undoubtedly essentially the same as that applied by De Montcheuil to an express passenger locomotive on the Montereau & Troyes Railway in France about 1850. This construction is shown in Figs. 2, 3, and 4. Here we find separate elements, coupled to a header, and

the elements located in a number of large fire tubes in the barrel of the boiler. The hot gases, in passing from the firebox to

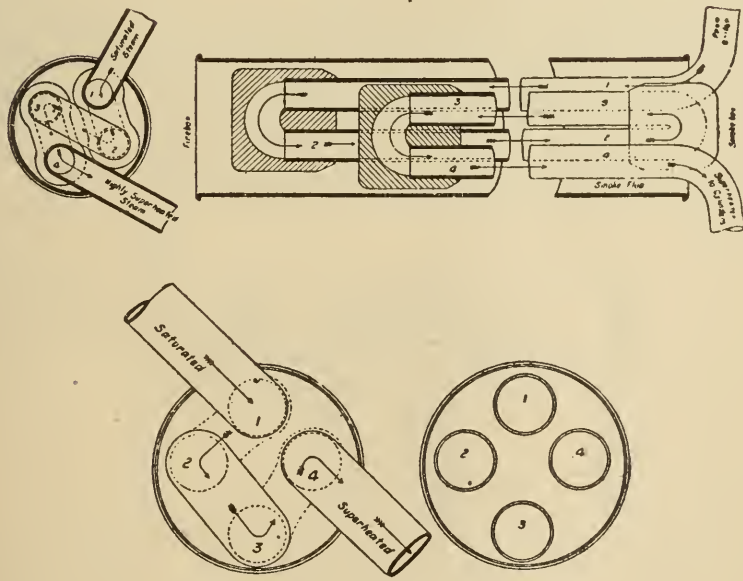
FIG. 3.



DE MONTCEUIL'S SUPERHEATER, 1850.

In all essential details this superheater is the same as the Schmidt fire tube type now used.

FIG. 4.



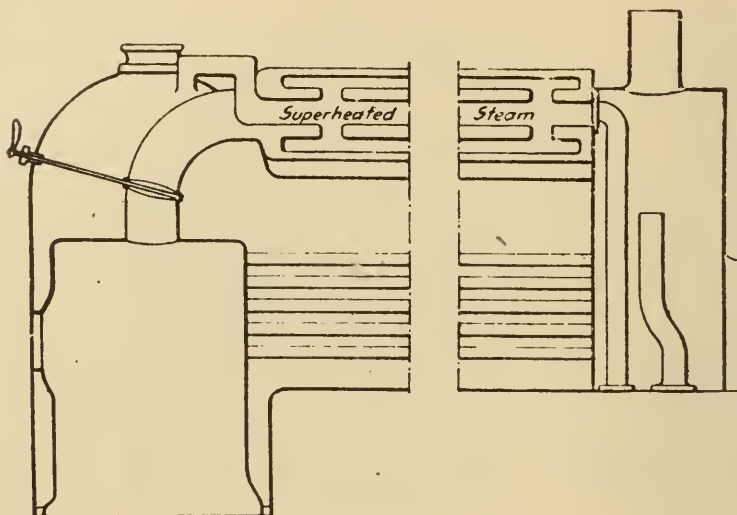
DE MONTCEUIL'S SUPERHEATER, 1850.

Details of the superheater element in the fire tube.

the smokebox, surround these small superheater elements, through which saturated steam is allowed to flow from the

throttle of the locomotive to the steam chest, and in the passage through the heated elements this steam becomes superheated, due to its separation from the steam in the boiler.

FIG. 5.

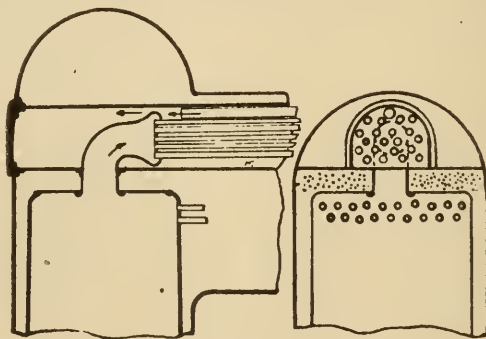


DE MONTCHEUIL'S SUPERHEATER, 1850, FIRE TUBE TYPE.

The gases are conveyed through a large tube connected to the crown sheet of the firebox. This early form of superheater shows the use of a damper in the gas passage.

Fundamentally, this design represents the most advanced practice of to-day in the production of superheated steam. Improvements in construction over that shown in these figures tend

FIG. 6.



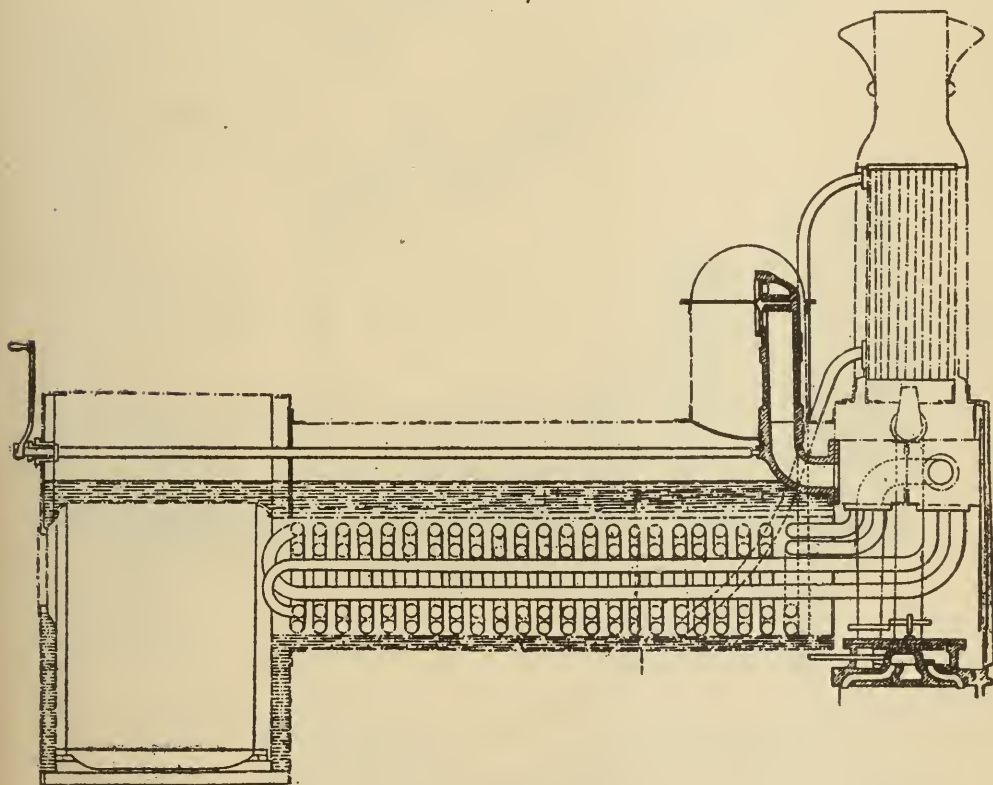
LLOYD'S SUPERHEATER, 1851, FIRE TUBE TYPE.

This superheater is very similar to that shown in Fig. 5.

largely to the perfection of details to minimize the cost of maintenance and the possibility of failure in service. It may therefore be said that De Montcheuil paved the way for future suc-

cessful designs, but his own experiments probably did not work out satisfactorily in practice, due to difficulties in the handling of the steam after superheating, from lubrication and packing troubles, and the general use of superheated steam for locomotives appeared to have been delayed for nearly fifty years, owing to these practical considerations which had to be worked out in the use of the high temperature steam. De Montcheuil devised at about the same time another form of superheater as shown in

FIG. 7.



MONTELY'S SUPERHEATER, 1855, FIRE TUBE TYPE.

The superheating element consists of a coil in a large fire tube. The early form of the Schmidt superheater is similar (see Fig. 11).

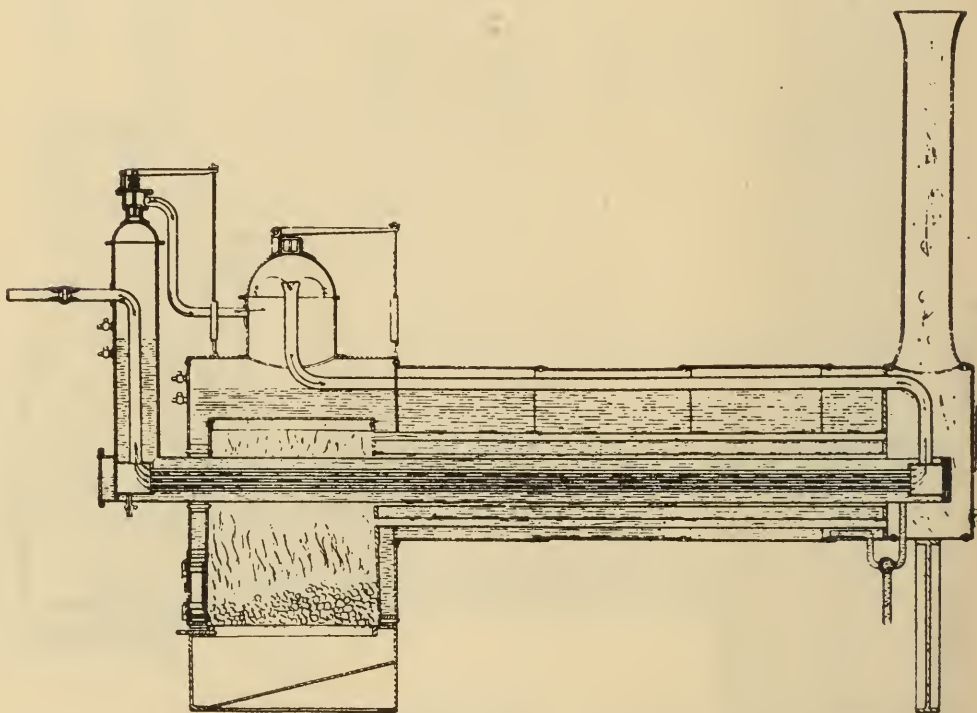
Fig. 5. It is interesting to observe that at this early date he proposed a damper to check or retard the flow of furnace gases over the superheater, to provide against its becoming overheated.

Following De Montcheuil we find, in the year 1851, that Richard Lloyd, residing in Paris, invented a modification of this superheater in which the tubes for superheating were in communication with the crown sheet of the boiler to utilize the heat of the gases after they had left the firebox, rather than after they

had left the front tube sheet. Fig. 6 gives an idea of the construction.

A superheater invented in 1855 by P. J. C. Montely, of Toulon, France, is shown in Fig. 7. The diagram illustrates an attempt of the inventor to provide a construction which would satisfactorily superheat the steam and at the same time utilize some of the heat of the waste gases for this purpose. The placing of the superheater element tubes in the barrel of the boiler in one large flue was an early use of a construction revived by

FIG. 8.



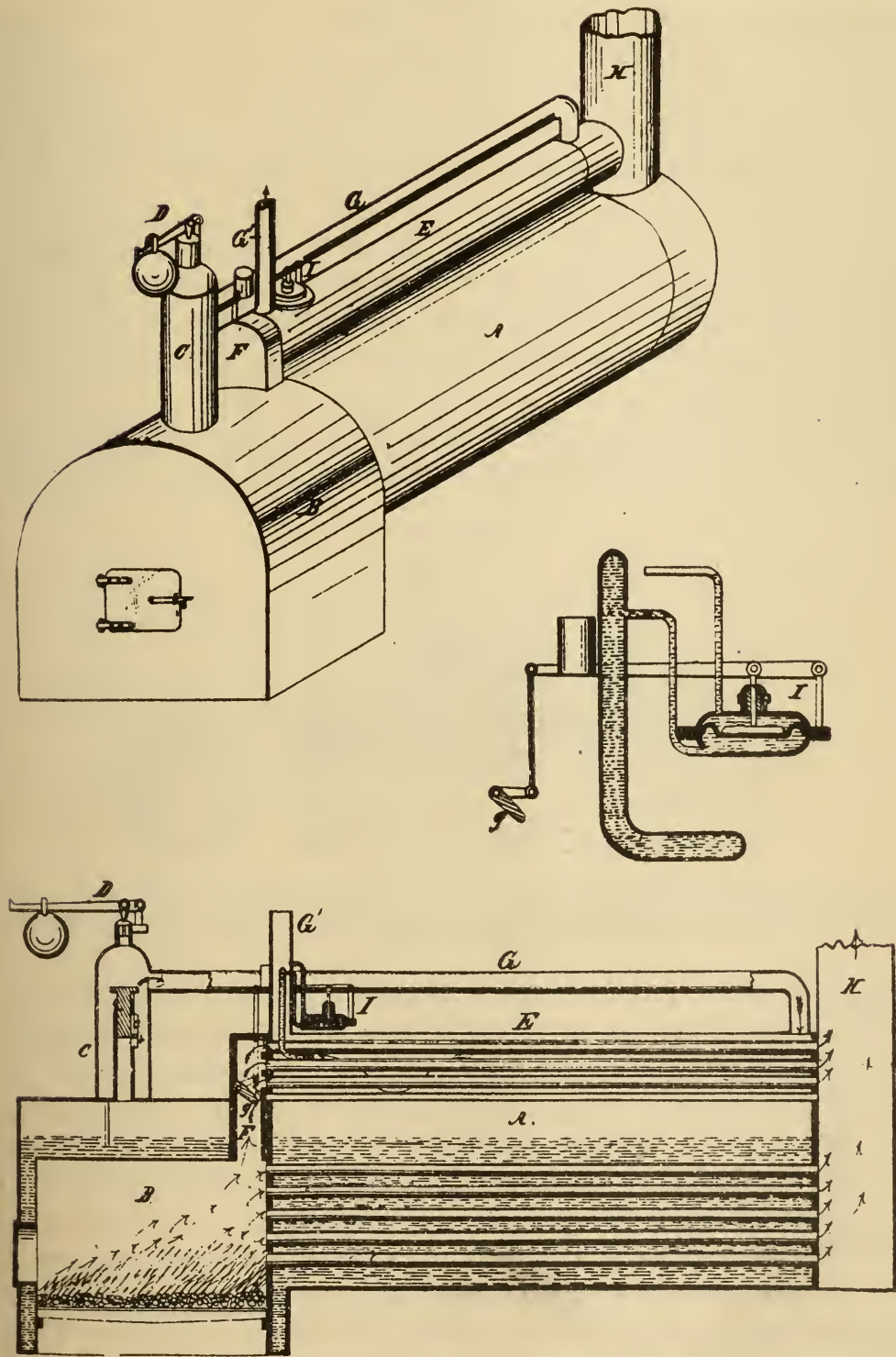
STORM'S SUPERHEATER, 1857, FIRE TUBE TYPE.

In this scheme for a superheater the elements are surrounded by water.

Schmidt in 1898, but later abandoned, owing to difficulties in keeping steam-tight the large flue in which the elements were placed.

The first United States patent for a fire tube superheater was issued to W. M. Storm, of New York City, in 1857. His object was to effect economy in the use of steam by placing the superheater in the boiler without exposing it to the direct action of the fire or hot products of combustion. By referring to Fig. 8 it is seen that his arrangement consists of a comparatively long

FIG. 9.



STILLMAN & WILCOX SUPERHEATER, 1859, FIRE TUBE TYPE.

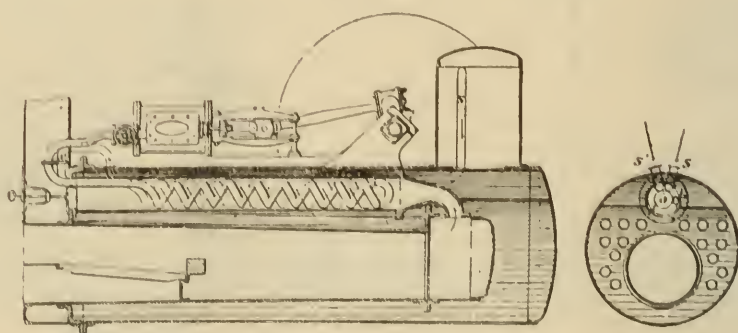
This superheater is outside of the boiler and part of the hot gases are deflected and passed through a large tube containing the superheater elements. Another early suggestion of a damper for the furnace gases is shown.

internal flue, one end terminating in the smokebox and the other end extending entirely through the firebox. This superheater and several others, as applied to locomotives, have the inherent defect of being inclosed by the cooler water or steam in the boiler, and therefore the superheat, if any is added to the steam, is later, to a considerable extent, returned to the boiler before reaching the steam chest.

The idea of this inventor was that hot gases from the furnace, coming directly in contact with the superheater elements, would rapidly deteriorate them and necessitate frequent renewals; for this reason he endeavored to protect them from direct action of the flame.

Stillman & Wilcox, of Westerly, Rhode Island, in 1859 were granted letters patent for a construction (see Fig. 9) in which

FIG. 10.



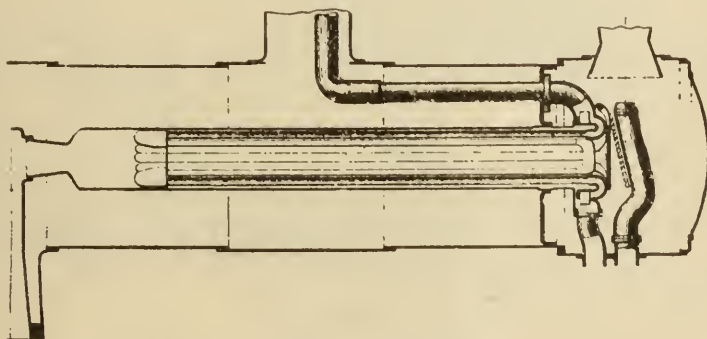
WEYER, LOREAU & CO. SUPERHEATER, 1860, FIRE TUBE TYPE.

The furnace gases are passed through a large return flue and in this flue there is a superheating coil. A hand-operated damper is used to control the flow of furnace gases.

a portion of the hot furnace gases are by-passed from the water tubes of the boiler to superheater elements encased in a jacket applied above the usual barrel of the boiler. In this case we see hot furnace gases passing directly to the elements. It is interesting, however, to observe that the inventor claims that by the use of this device he could regulate the flow of the products of combustion to the superheater by a damper, operated by the difference in pressure between the superheated and saturated steam, and that as early as 1859 it was recognized that this damper was, under certain operating conditions, desirable, if not necessary, just as the control of the furnace gases, either through the fire tubes of the boiler or through the large flues which contain the superheater elements, is an important feature of successful superheater practice to-day.

Weyher, Loreau & Company, of France, in 1869 obtained a patent covering a construction which has been little used, but which again illustrates the division of the furnace gases. A large flue contains the superheater elements in the form of a double coil. It is apparent from Fig. 10, and the one just referred to, that it was early recognized that at certain periods, depending upon the consumption of steam by the engine, the flowing gases had to be regulated in order not to overheat the superheater elements or to furnish steam of too high a temperature to the cylinders. Judging from the extent of the use of superheated steam upon locomotives, none of the early attempts were successful, because the design of the superheater did not overcome the obstacles presented in the operation of both boiler and engine, due to the higher temperature involved; and it was not until

FIG. 11.



SCHMIDT SUPERHEATER, 1897, FIRE TUBE TYPE.

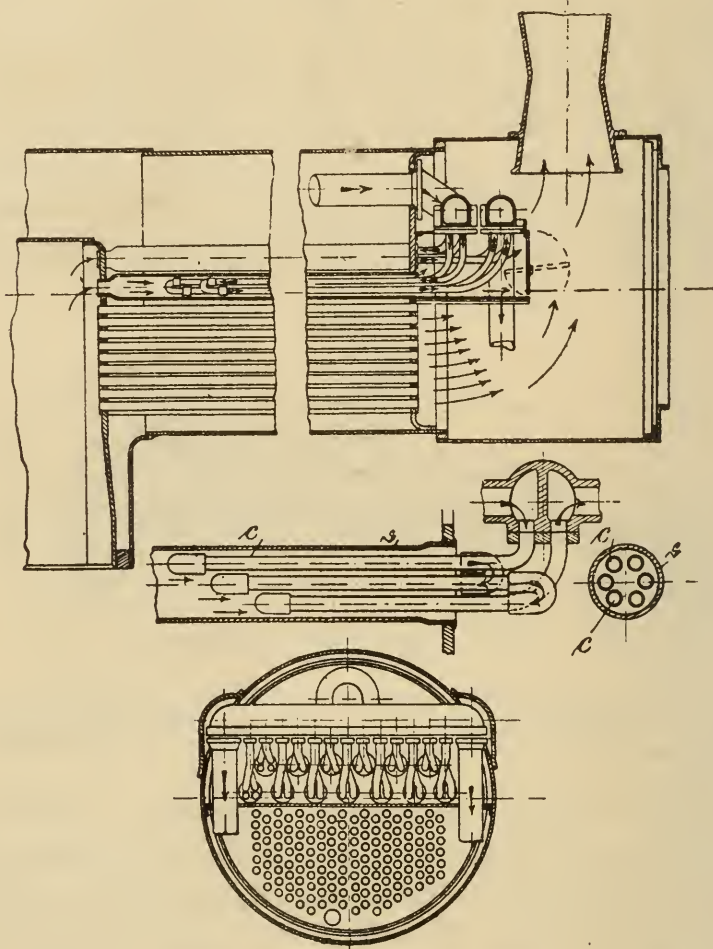
An early form of the Schmidt superheater now so much used. The large flue gave trouble from leakage and filling with cinders, and the arrangement was abandoned.

1897, when Dr. William Schmidt, of Germany, working in conjunction with Mr. Robert Garbe, of the Prussian State Railways, developed a superheater which laid the foundation for the extended application which we find to-day. Schmidt, having gained experience in applying superheated steam to stationary engines, paid particular attention to the perfection of lubrication and the maintenance of tight packing when using high-temperature steam, and in 1897 produced a design which was applied to a locomotive, as shown in Fig. 11. As already mentioned, this design was abandoned owing to the difficulty experienced in keeping tight the large flue in which was placed the group of superheater elements, as well as to trouble with this flue, due to its stoppage with cinders. His first change was to use a smokebox type of superheater in which a portion of the gases

from the furnace was passed through a large flue in order to provide sufficient heat to obtain a high temperature of the steam; this construction will be mentioned later under the smokebox type.

The invention of Schmidt and Thomsen in 1902 is illustrated in Fig. 12. A header for collecting and distributing the saturated

FIG. 12.



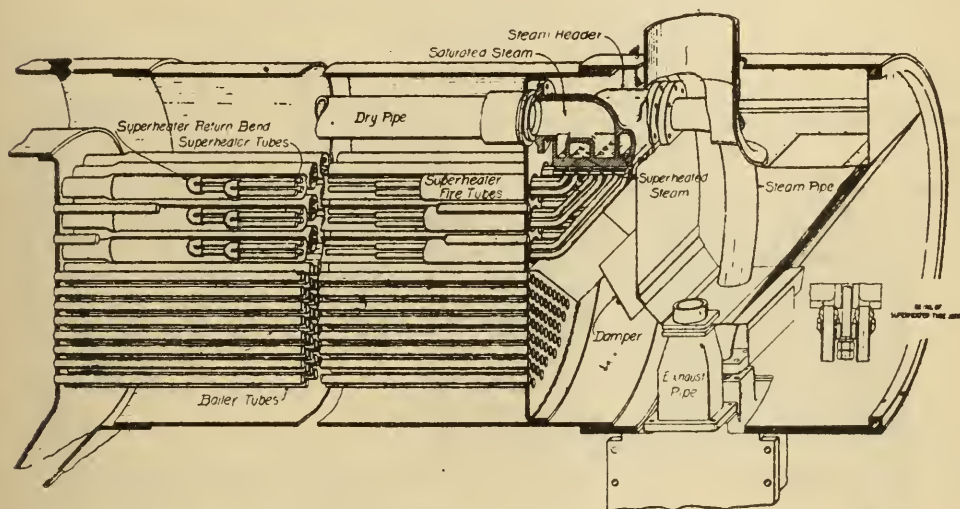
SCHMIDT & THOMSEN SUPERHEATER, 1902, FIRE TUBE TYPE.

A second form of the Schmidt superheater in which the elements are separated and placed in a number of large flues.

and superheated steam is employed, and attached to it are superheater elements enclosed in large fire tubes adjacent to and above the usual fire tubes of the locomotive boiler. A damper is provided in front of the flues containing the superheater elements, to confine, when desired, the hot furnace gases to the lower and smaller fire tubes of the boiler. The similarity of this construction to the one shown in Fig. 3, that by De Montcheuil in 1850,

is striking. All of the elements of the De Montcheuil design are found in the Schmidt construction excepting the damper and the combination saturated and superheated steam header in two distinct parts, for it will be noted that De Montcheuil carried his superheated steam down the sides of the smokebox rather than across the top. It was found with this construction that any desired superheat could be obtained by a proper proportion of superheater heating surface to water-heating surface, and therefore Schmidt obtained the high superheat of which he is a strong advocate. Not only did he obtain high temperatures, but by careful study of the proper means of lubrication and by special de-

FIG. 13.



SCHMIDT SUPERHEATER, FIRE TUBE TYPE.

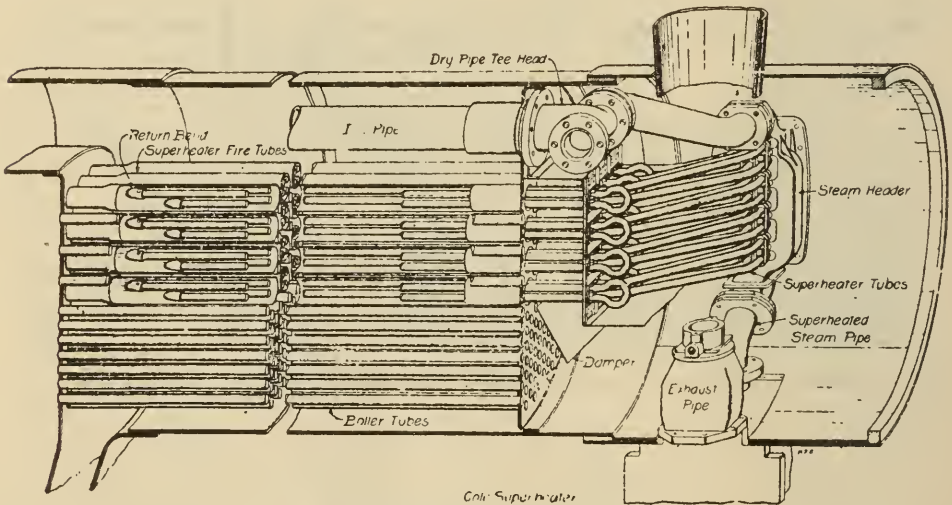
This shows the form of the superheater now in general use. It consists of a steam header and superheating elements, consisting of small tubes making two passages through the hot gases in a number of large fire tubes. There is a damper to check the flow of hot gases when steam is not flowing through the superheater.

signs of valve stem and piston-rod packings, as well as of valve and piston packings, he successfully used this highly superheated steam.

Fig. 13 illustrates again the Schmidt construction as used today in this country and in Germany and it is interesting to see that in this arrangement there is a combination casting for the saturated and superheated steam, and below the elements a damper. A detail of the superheater tube joint is also illustrated, as the perfecting of this joint was one of the difficulties encountered in the maintenance of this superheater, and the construction, as shown, largely overcame the trouble which had been experienced in maintaining the superheater steam-tight at the

header casting. It is seen from this figure that the gases from the firebox pass through both the boiler and the superheater fire tubes when the damper is open. When the damper is swung to a closed position the gases cannot pass through the superheater fire tubes, and thus a protection is afforded against over heating; the small tubes can convey all of the hot gases when the damper is closed. This damper is operated by a small steam cylinder which is actuated by the pressure in the steam pipe immediately above where it enters the steam chest, so that when the throttle is opened, and there is pressure in the steam pipes or steam chest, the damper opens, and when the steam is shut off at the throttle this damper closes by gravity and blocks off the flow of the

FIG. 14.



COLE SUPERHEATER, FIRE TUBE TYPE.

This superheater differs from the Schmidt in having a side header instead of a top header.

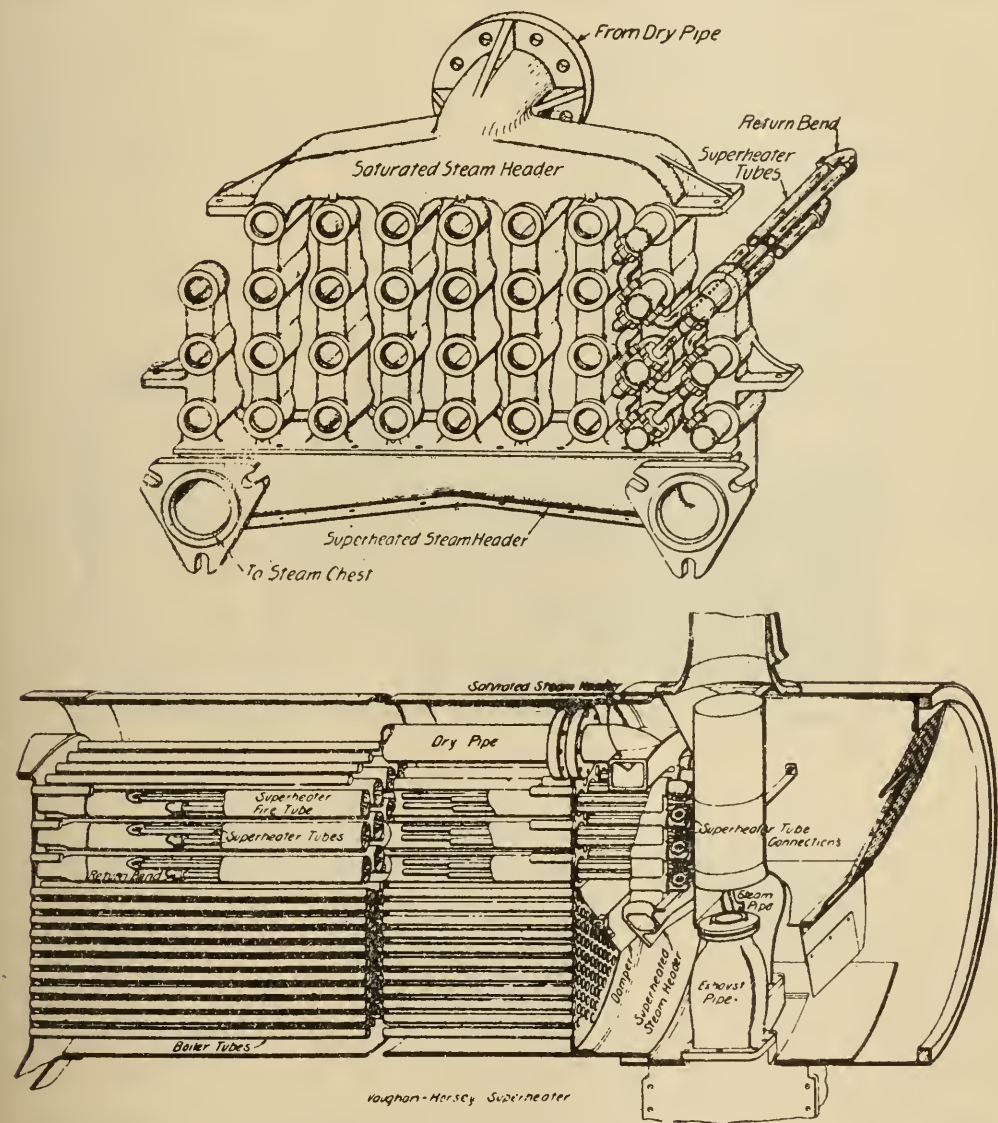
furnace gases through the fire tubes containing the superheater elements.

Following the success of Schmidt in maintaining good lubrication and packing with the use of highly superheated steam, Mr. F. J. Cole, of Schenectady, N. Y., brought out a side-header superheater which is shown in Fig. 14. A glance at this figure will serve to illustrate the construction, and it will be seen that the top header of the Schmidt device has been divided into two side headers to which are attached the superheater elements. They are attached by a different means, however, from that shown in detail in Fig. 13 of the Schmidt construction.

Mr. H. H. Vaughan, of Montreal, Canada, introduced and

has in operation a large number of locomotives equipped with the design shown in Fig. 15 and known as the Vaughan-Horsey superheater. Here again we have all of the essential parts found in the De Montcheuil, Schmidt and Cole construction, with the

FIG. 15.



VAUGHAN-HORSEY SUPERHEATER, FIRE TUBE TYPE.

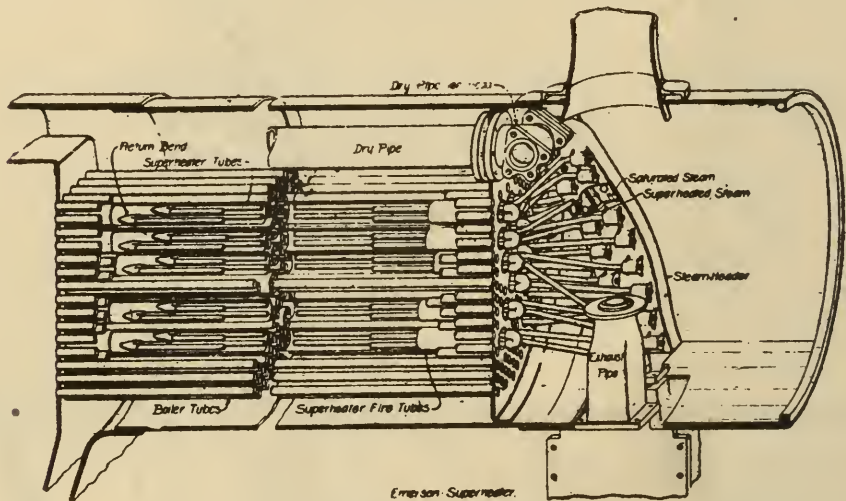
In this superheater all of the essential parts of the Schmidt construction appear. The header, instead of being above the elements, is in front of them. The superheater elements are connected to the header by a connection similar to a pipe union.

exception that the saturated steam header is in front of the tube sheet, instead of at the top or sides. The superheater elements are attached to the two separate headers by means of coupling nuts which are of a special design to provide against the exces-

sive heat of the gases at this point. The early introduction of highly superheated steam on the Canadian Pacific Railroad was accomplished by the design as shown in this figure.

The Emerson superheater as applied upon the Great Northern Railway is illustrated in Fig. 16. In this construction the superheater elements are fastened to the headers formed by the steam pipes in the smokebox by the usual method of expanding with a roller. The hole through which the expander is inserted is afterwards closed with a screw plug. The superheater is but another modification of the prevailing type in the details involving maintenance features.

FIG. 16.



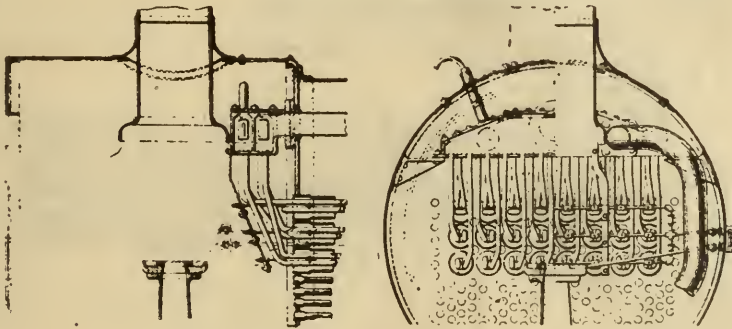
EMERSON SUPERHEATER, FIRE TUBE TYPE.

In this form of superheater the steam pipes on each side of the smokebox are used as headers, and the elements are connected by expanding the tubes:

In England, Mr. J. C. Robinson is using a superheater, the general construction of which is shown in Fig. 17. Here again we see a top header casting for both the saturated and superheated steam. The tubes or elements in this case are not bolted to the header but are prossered into it with the usual form of expander. The interior of the header is accessible by the removal of cover plates. A feature peculiar to this design is the manner in which the gas flow from the flues containing the superheater elements is stifled when the locomotive is not working. This is accomplished by steam jets which are introduced at the front end of the flues. The flow of steam from these jets, when the throttle

is closed, overcomes the vacuum of the smokebox and blocks the passage of the hot furnace gases through these tubes. It is claimed that the application of these steam jets aids in reducing the quantity of cinders which tend to collect about the superheater elements in the large fire tubes.

FIG. 17.

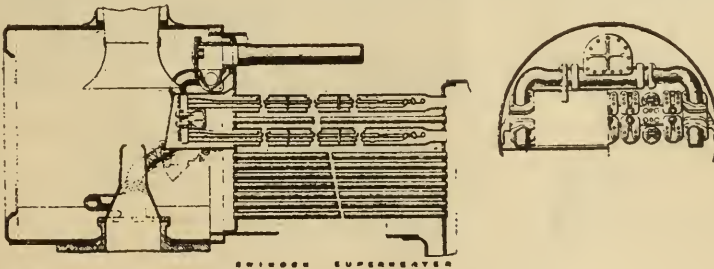


ROBINSON SUPERHEATER, FIRE TUBE TYPE.

This is an English superheater. The elements are connected to the header by expanding the tubes. Instead of a damper, there are steam jets which baffle or check the flow of gases when the superheater is out of service. These steam jets also serve to blow out the cinders and dust from the elements.

On the Great Western Railway of England a number of locomotives have been fitted with the Swindon superheater as shown in Fig. 18. Here again the usual construction is evident, with

FIG. 18.



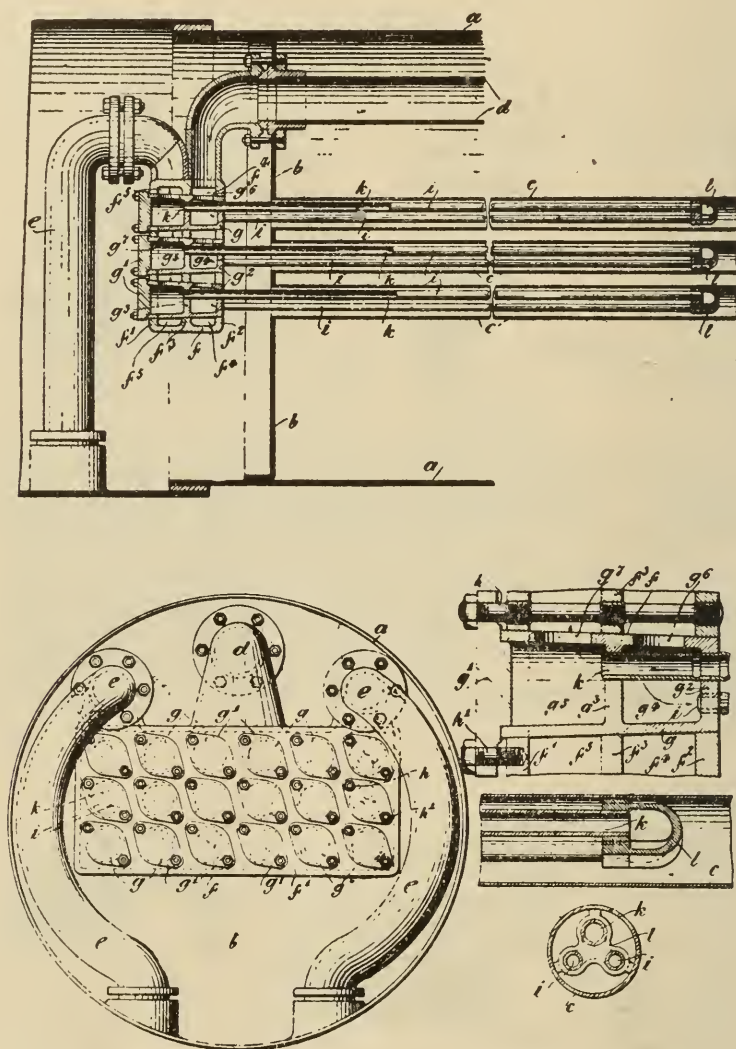
SWINDON SUPERHEATER, FIRE TUBE TYPE.

This is an English superheater. The header is in front of the elements. Each of the elements consists of three double tubes which are expanded into the heater.

the exception that a change is made in the manner of fastening the elements to the header. In this design the elements consist of a set of three double tubes which are expanded into a casting of horse-shoe shape, one side of which is connected with the

saturated portion of the header and the other receives the superheated steam. A damper is provided at the bottom of the box through which the flowing gases pass from the superheater elements.

FIG. 19.



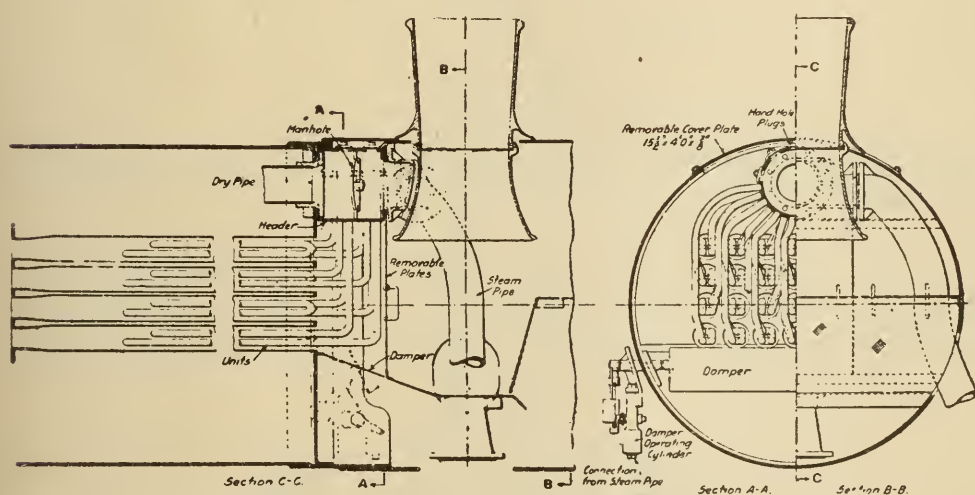
VAUCLAIN SUPERHEATER, FIRE TUBE TYPE.

In this superheater the header is in front of the elements. The elements are expanded into tapered cylindrical castings, and these castings are inserted into the header. Each element consists of one large tube with two smaller return tubes.

An illustration of a patent granted to Mr. S. M. Vaucrain, of Philadelphia, Pa., in 1912, is shown in Fig. 19. The arrangement of the elements in the fire tubes is novel, in that the steam from the vertical saturated steam header first passes through one

tube and returns to the header through another tube. The method of fastening the elements to the header seems to have been devised with the idea of reducing to a minimum complications in the construction of the header casting, and in order to accomplish this a number of additional joints are required. The superheater element tubes are attached to the header casting by expanding the tubes in the manner generally practised in boiler construction, and bolted caps are provided for the openings through which tools are inserted in the tubes.

FIG. 20.



FOSTER SUPERHEATER, FIRE TUBE TYPE.

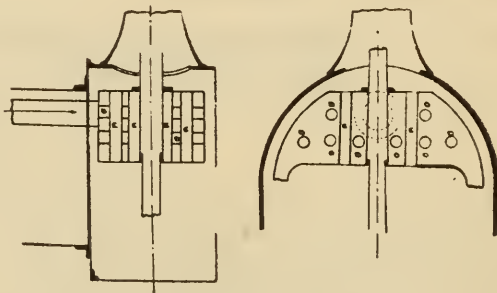
In this superheater the header consists of a steel plate drum into which the elements are expanded. The tube ends can be fastened without entering the smokebox or interfering with the internal arrangement of it. There is the usual damper for controlling the flow of gases.

The Foster superheater, which has been devised for the purpose of reducing the number of parts and to overcome difficulties in maintaining the superheater header casting, is shown in Fig. 20. In this construction a steel drum is substituted for the cast saturated and superheated steam header and the element tubes, by a series of bends, are introduced into the drum and fastened by the usual boiler tube expanding tool. This construction permits of the fastening of these tubes without interfering with the internal arrangement of the smokebox as applied to a locomotive. A special damper for controlling the flow of hot gases from the furnace, as in most of the other modern superheaters, is employed.

SMOKEBOX TYPE.

Next in importance to the fire tube type is the smokebox type, which was at one time looked upon with great favor, as it was thought that a superheater of this type would utilize the heat in

FIG. 21.

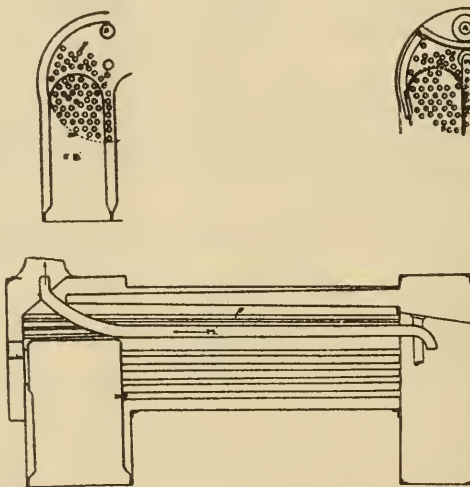


HAWTHORN SUPERHEATER, 1839, SMOKEBOX TYPE.

The smokebox superheater is an attractive arrangement, as there is a possibility of utilizing heat which would otherwise be lost. It introduces, however, an interference with the flow of gases, and this has limited its use. It will be noted that this type was suggested at a very early date in the history of superheating.

the waste gases from the boiler which would otherwise be lost by passing out through the stack. Trials of this type, however, developed the fact that the interference with the flow of gases

FIG. 22.



HAWTHORN SUPERHEATER, 1839, SMOKEBOX TYPE.

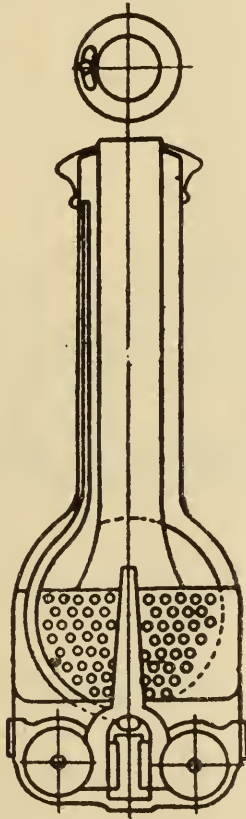
The boiler has a return tube in which the superheater is located. It was suggested that this arrangement be used either separately or in conjunction with the smokebox superheater.

in the smokebox, together with the accumulation of cinders, reduced the available output of the locomotive, and therefore it could not be considered as desirable as the fire tube type.

A complete description of a test of a freight locomotive, equipped with a superheater of this type and tested at the Locomotive Testing Plant of the Pennsylvania Railroad, can be found in their Bulletin No. 13, entitled "Smokebox Superheater."

R. & W. Hawthorn, contemporaries of Trevithick, in 1839 had a patent issued to them in which one arrangement proposed

FIG. 23.



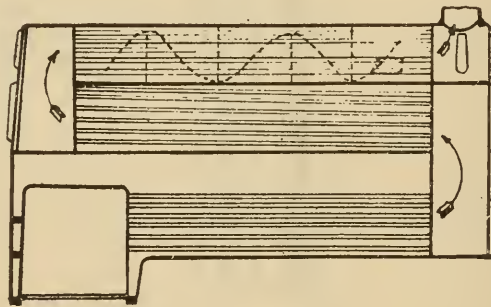
COCKERILL SUPERHEATER, 1848, SMOKEBOX TYPE.

In this Belgian superheater the elements are in the smokebox and extend to the top of an enlarged smokestack.

the superheating of the steam entirely within the smokebox. The apparatus is shown in Fig. 21, the steam passing through a pressure tight steam box, and the gases from the furnace, after leaving the tubes, flow both vertically and horizontally through tubes in this steam chamber. Another arrangement proposed by them is shown in Fig. 22, in which the apparatus consists of return fire tubes which occupy a space above the water tubes of the boiler, and it was proposed that this arrangement be used

either separately or in conjunction with smokebox superheating. It is thought that this invention originated not so much from the work of Trevithick in 1832 as from the suggestion made by Joseph Perkins, who in February, 1837, conceived the idea of employing superheated steam in locomotives. A paper by Perkins establishes the fact that the essential principles of superheating were then known. According to Perkins's patent, he mixed with the superheated steam a certain proportion of water to obtain, as he said, a steam in the perfect state and from his data he concludes "experience shows that when water is heated in tubes entirely in contact with fire, the steam generated possesses greater, or less, temperature." It would seem that the Hawthorn inven-

FIG. 24.



COWPER SUPERHEATER, 1851, SMOKEBOX TYPE.

This is a superheater arrangement to recover heat in the waste gases, superheating by means of the gases as they flow through a third pass outside of the boiler.

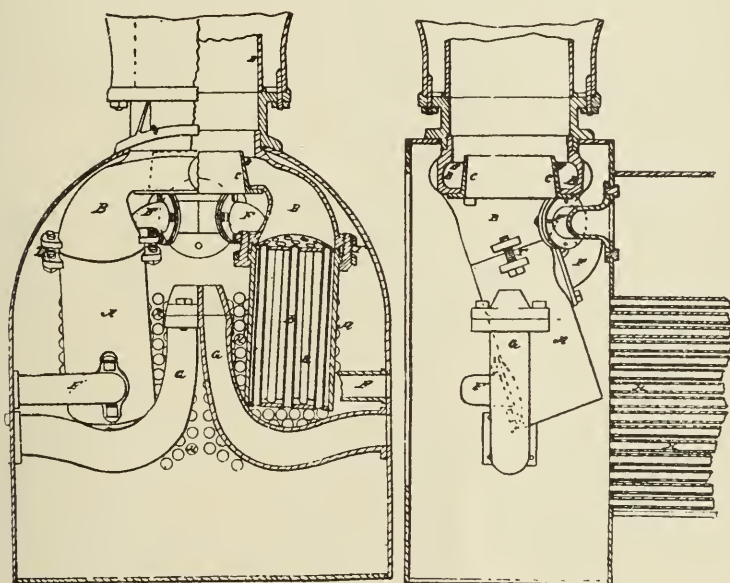
tions were intended to provide a means of obtaining the effect suggested by Perkins.

Nine years later, or in 1848, there were applied to six locomotives, built by the firm of John Cockerill in Belgium, superheaters arranged around the smoke stack, as shown in Fig. 23. By the arrangement employed the steam in its passage to the cylinders was superheated from the waste gases of the boiler, and in order to provide insulation to retain such heat as the steam collected, material of felt and wood was inserted between the superheater and the stack. This superheater also provided for a very large capacity in the steam chamber. It was stated in the description that "this arrangement has demonstrated that by the generation of the steam, due to the high steam pipe, the steam entered the cylinder entirely dry."

Following the work in Belgium, Chas. Cowper in 1851 ob-

tained a patent for an invention very similar to that of Hawthorn, in which he makes use of the waste gases from the boiler, superheating by means of these waste gases in the third pass toward the stack, the gases having made the second pass in the boiler through fire tubes. This arrangement is shown in Fig. 24 and is merely a modification of the scheme proposed by Hawthorn and shown in Fig. 22, requiring the flowing gases to pass forward in their third pass to the stack of the locomotive. It is interesting to observe, however, that baffles were placed in the super-

FIG. 25.



MARTIN SUPERHEATER, 1860, SMOKEBOX TYPE.

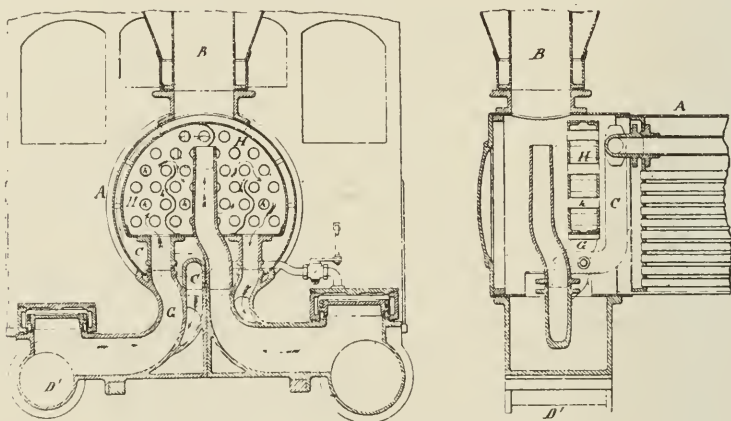
This superheater consists of two vertical drums in the smokebox. All of the gases are required to pass through tubes in these drums, and the drums form a part of the steam pipes.

heater chamber, in order to increase the length of passage of steam in flowing from the throttle to the steam chest. This same arrangement was later employed in the barrel type of superheater, which Cowper was the first to propose and which is shown in Fig. 34.

A much more elaborated installation is shown in Fig. 25, suggested by J. Martin in 1860. This arrangement differs from other attempts at smokebox heating in that the superheater chambers are of the drum type and make up a portion of the steam pipes connecting the throttle and steam chest. All of the gases of combustion were required to pass through the tubes of the superheater steam drums.

The tubes in the drums of the Martin construction were vertical, whereas in 1873 W. S. Hudson, of New Jersey, proposed a similar scheme in which the tubes for the passage of gases are horizontal and directly in front of the tube sheet. This ar-

FIG. 26.

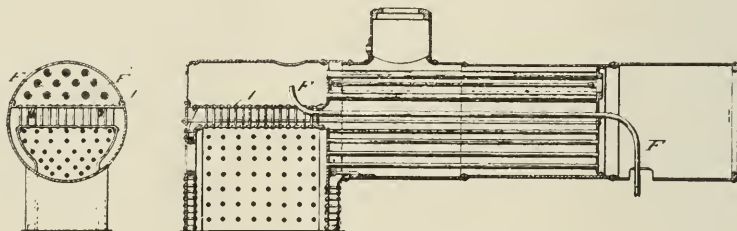


HUDSON SUPERHEATER, 1873, SMOKEBOX TYPE.

This superheater consists of horizontal tubes in the smokebox. It is the first instance of a superheater designed to heat the steam between the high and low pressure cylinders in compounding.

rangement is shown in Fig. 26, and is of particular interest as it shows one of the earliest arrangements for heating the steam when compounding, in that the heater is used only for drying the steam after it has left the high-pressure cylinder, but while

FIG. 27.



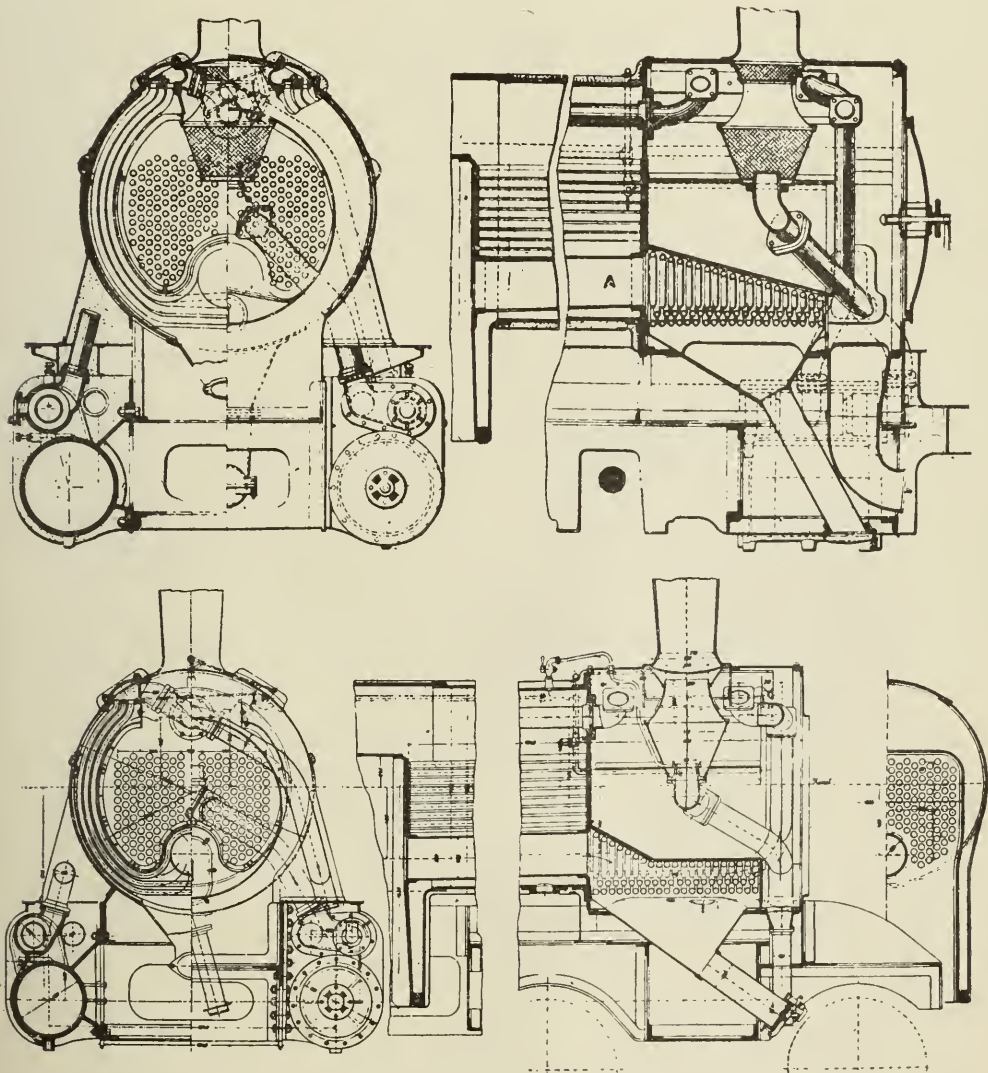
COVENTRY SUPERHEATER, 1885, SMOKEBOX TYPE.

This arrangement of superheater is very similar to that proposed by Hawthorn in 1839. Superheating is accomplished by returning the fire tubes through the steam space of the boiler.

it is still retained in the receiver, the receiver in this case being the smokebox superheater. In the claim of his patent, however, he does not confine the use of his superheater to superheating purposes only.

Chas. B. Coventry, of Chicago, in 1885 secured letters patent upon a waste gas superheater for locomotives, as shown in Fig. 27. This arrangement is but a slight modification of that proposed by Hawthorn in 1839 and consists in a change in form of

FIG. 28.



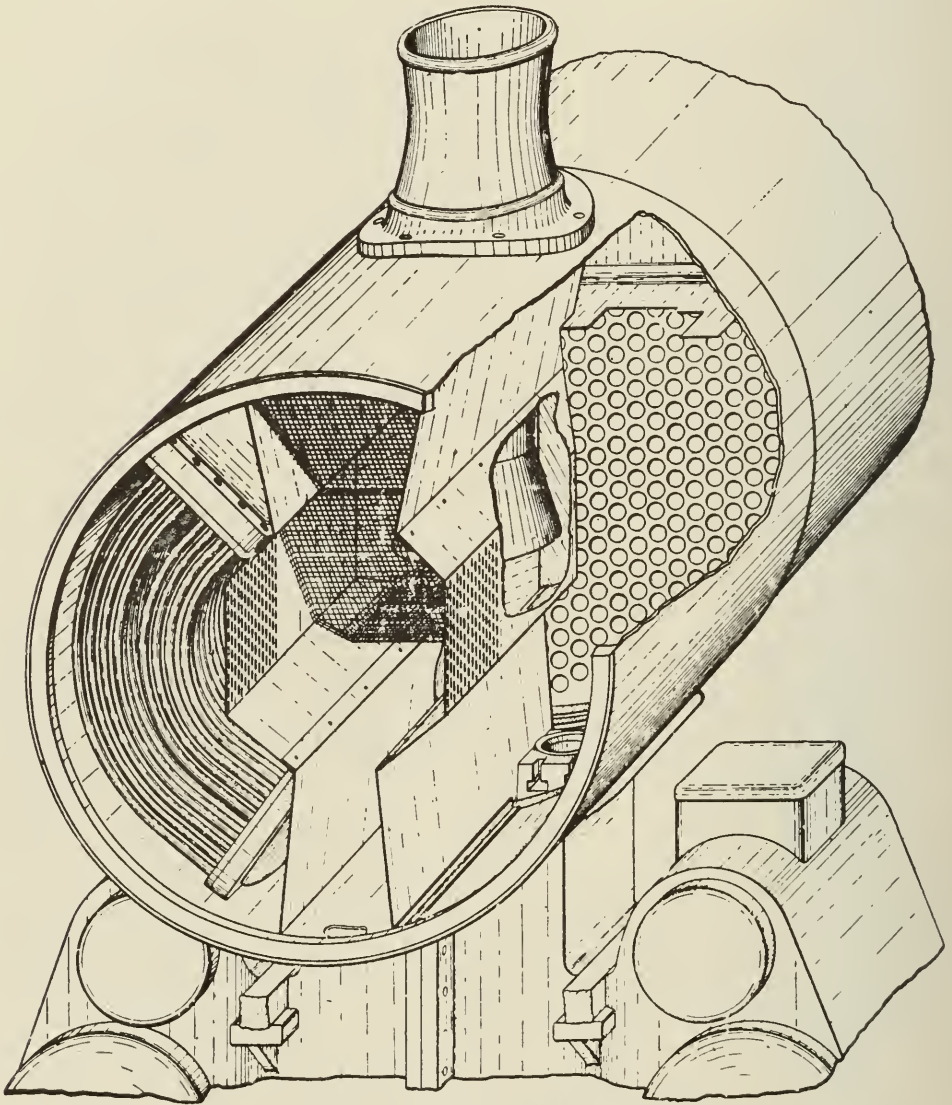
SCHMIDT SUPERHEATER, 1898, SMOKEBOX TYPE.

These two drawings show the second arrangement adopted by Schmidt. He endeavored to obtain a high superheat by using hot gases from the firebox, but with the superheater entirely within the smokebox. This superheater was extensively used, but has been superseded by a later form.

the roof sheet of the firebox to form a portion of the smokebox chamber. Difficulties involved in the boiler construction and maintenance precluded any use of the suggested modification in view of the small amount of superheat derived.

As already mentioned in reference to the work of Schmidt in the development of superheaters, the second form proposed by him was of the smokebox type as shown in Fig. 28. This he developed in 1898 after the trouble experienced with his first

FIG. 29.



BALDWIN SUPERHEATER, SMOKEBOX TYPE.

This superheater consists of two banks of tubes which form part of the steam pipes in the smokebox. The gases are required to flow between the tubes by means of baffle plates. A moderate degree of superheat is possible with this arrangement.

superheater, which was shown in Fig. 11. This early form developed leaks in the large flue and a difficulty in keeping the small superheater tubes free from an accumulation of cinders. In this later arrangement a portion of the hot furnace gases are

carried through a large flue in the boiler and then through a cast iron chamber containing a nest of tubes which convey the steam between the throttle and the steam chest. The plan did not contemplate the production of low-temperature superheat, and for this reason the construction can hardly be called a typical waste gas or smokebox superheater, as is to be observed by reference to Fig. 28. The hot gases, after passing around small superheater tubes, are discharged at the top into the smokebox and thence out of the stack.

A low-temperature superheater of the smokebox type in which all of the gases, after they have left the fire tubes of the boiler, were forced to sweep past small superheater elements forming a portion of the steam pipe, was proposed by Mr. S. M. Vauclain of the Baldwin Locomotive Works and tried upon the Pennsylvania Railroad. This arrangement is shown in Fig. 29, and the results obtained with it have been reported in Bulletin No. 13 issued by that road. This superheater was also applied to a number of locomotives by other railroads in this country, but owing to its general effect upon the locomotive as a whole, as already mentioned, has been discontinued.

Directed by two vertical partitions the gases first pass around the smokebox walls, then return to the central portion of the smokebox and from this point are exhausted from the stack.

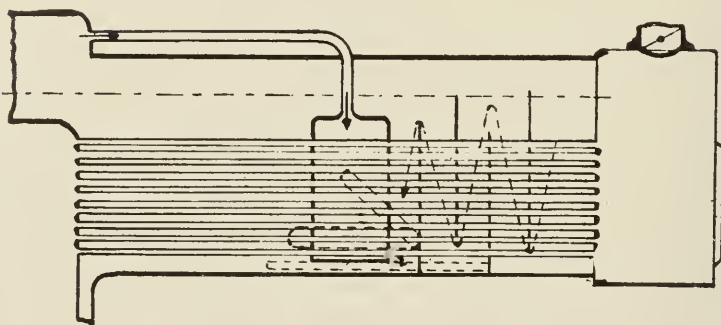
BARREL TYPE.

Quite a different form of superheater, and of very simple construction, is that known as the barrel type, one of the earliest forms being shown in Fig. 30; the superheater in this case consists of a superheating box within the boiler and surrounding the middle part of the fire tubes. This box is usually composed of two tube plates through which the boiler tubes pass. Saturated steam from the boiler is admitted to this partitioned superheater box and from it is conducted to the steam cylinders. The superheat gained by the steam in this box is somewhat decreased during its passage to the cylinders, and this arrangement does not provide any means for keeping the superheater box cool when the throttle is not open. For these two reasons it apparently has not met with great favor. Fig. 30 represents what was proposed by Cowper in 1851. In addition, Cowper proposed that the feed water should enter the boiler at a point near the front tube sheet

and be baffled through a series of compartments in succession as shown.

In 1855, John Ermorine, of Lyons, France, suggested a scheme which is shown in Fig. 31. In this case the superheater

FIG. 30.

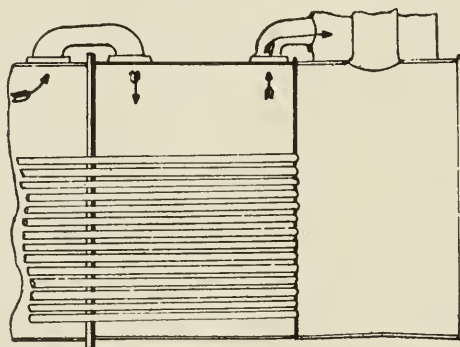


COWPER SUPERHEATER, 1851, BARREL TYPE.

This is an early form of the barrel type superheater, where the superheater consists of a box surrounding a part of the fire tubes. It causes an intermediate degree of superheat between that possible with the fire tube and smokebox types.

box was moved forward in the barrel so that the front wall of the superheater formed the front tube sheet. By this arrangement less loss in superheat in the passage from the superheater to the steam chest is encountered, but the arrangement only provides for a low degree superheat.

FIG. 31.



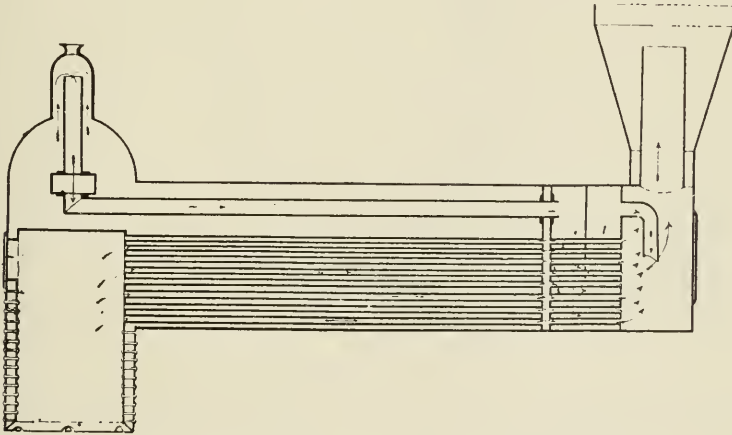
ERMORINE SUPERHEATER, 1855, BARREL TYPE.

In this barrel type superheater the smokebox end of the tubes is used, the forward tube sheet forming part of the superheater box.

In 1863, Benjamin Crawford, of Pittsburgh, Pa., obtained letters patent for an arrangement similar to the Ermorine, but with an improvement in the form of a baffle plate within the superheater box to cause the steam to pass to the lower tubes before it could leave the superheater, and thus obtain higher

superheat from a given amount of superheater heating surface. His superheater is shown in Fig. 32. The back wall of the superheater box was independent of the front tube sheet of the boiler.

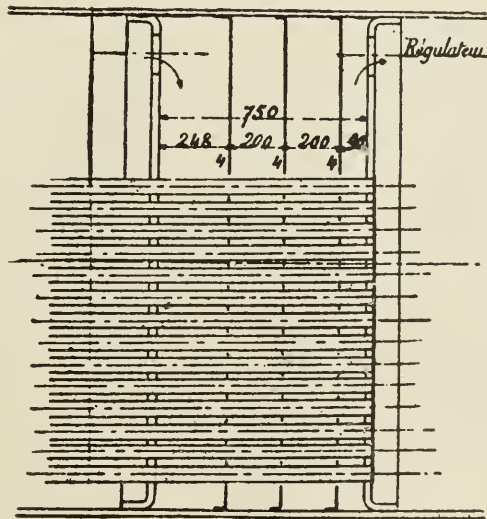
FIG. 32.



CRAWFORD SUPERHEATER, 1863, BARREL TYPE.

This superheater is very similar to the Ermorine, but it resembles more nearly the smokebox type, as it has a double tube sheet at the rear end.

FIG. 33.



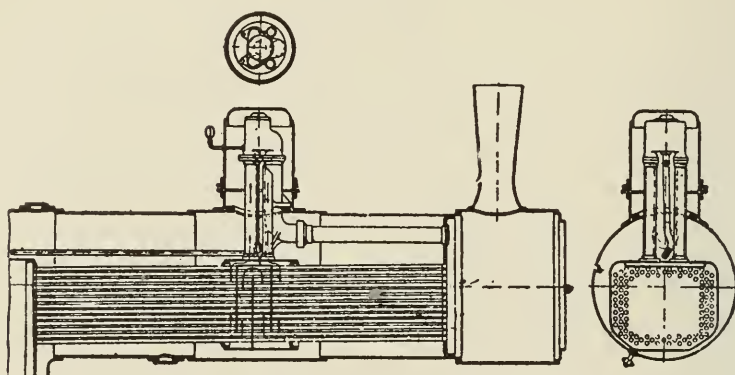
CLENCH-KING SUPERHEATER, 1896, BARREL TYPE.

This superheater is very similar to Crawford's, shown in Fig. 32. It has, however, more baffle plates.

In 1896, Clench-King, of France, designed a superheater arrangement quite similar to that of Crawford, with the exception that baffle plates are introduced into the superheating box and a simplification of the tube sheets is made. Substantially,

however, the two constructions are quite similar and produce only a moderate superheat. The Clench-King superheater is shown in Fig. 33.

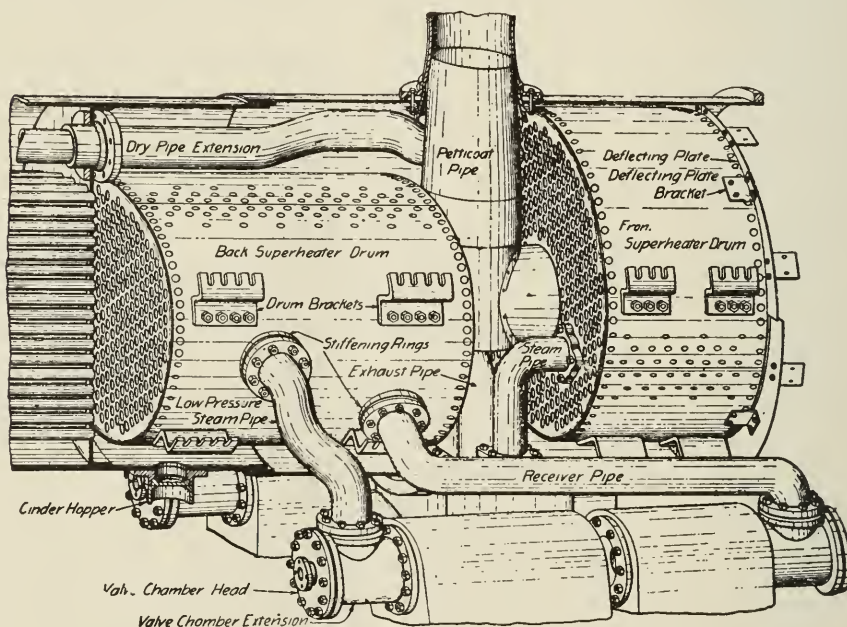
FIG. 34.



PIELOCK SUPERHEATER, BARREL TYPE.

This is a form of the barrel type which has been extensively used. The superheater is located about midway in the length of tubes and produces an intermediate degree of superheat.

FIG. 35.



JACOBS SUPERHEATER, BARREL TYPE.

This superheater consists of drums arranged in a manner very similar to that of Crawford's as shown in Fig. 32. In this illustration an arrangement of double superheater is shown for use in compounding, the steam being heated between the high and low pressure cylinders.

In Germany, at about this time, the Pielock superheater was introduced. It is located in the boiler barrel (see Fig. 34) in a manner similar to that proposed by Cowper and with the baffle

arrangement suggested by Crawford. This superheater was applied to a locomotive built for the Hannover Directorate of the Prussian Railway Administration and tested by the Pennsylvania Railroad on its Locomotive Testing Plant at the Saint Louis Exposition. A report of this test, under the title "Locomotive Tests and Exhibits, 1904," was published by the Pennsylvania Railroad. The tests indicated certain deficiencies in this form of superheater, as we have already noted.

Still another form of this general type of superheater was applied to a tandem compound locomotive built by the A. T. & St. F. Railway, the construction being shown in Fig. 35. Here it is seen that two steel drums are used for superheating the steam. The rear drum is made oval in cross-section to provide for the passage of the dry pipe connection to the other drum, these drums being placed directly before the front tube sheet of the boiler. The forward drum, which is circular in cross-section, is placed just ahead of the exhaust pipe and receives the saturated steam from the throttle. Within the drums are baffle plates to deflect the steam to the tubes contained within the drums. From the front drum the steam passes to the high-pressure cylinder, and the exhaust from this cylinder is received by the rear drum which reheats the steam for the low-pressure cylinders. The arrangement of a superheater of this character would seem to introduce serious interference with the passage of exhaust gases and cinders and would require a considerable vacuum in the smokebox in order to burn the coal in the firebox.

FIREBOX TYPE.

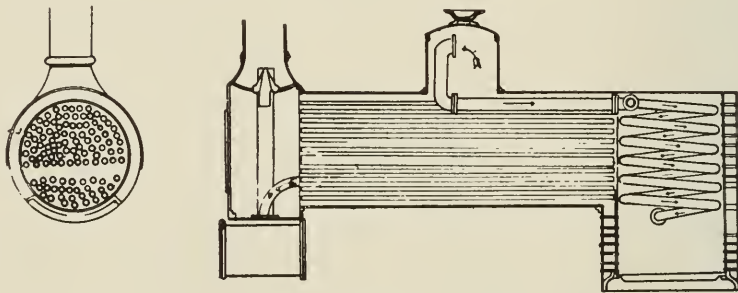
Little, if any, attention has been paid to the firebox type of superheater, and this is probably due to the difficulties experienced in providing a material which will withstand the heat of the firebox and remain steam-tight. This form of superheater has the distinct advantage over all others in that, for a minimum weight and the least heating surface, the highest possible superheat may be obtained. Constructive difficulties, however, seem to have been sufficiently great to have made this type impracticable with the materials now in use in boiler construction. It would seem, however, to have a future usefulness if materials can be found and so arranged that they will withstand high temperatures, and it is probable that future improvements of the

superheater will be directed toward this type or toward a modification of it.

As early as 1853 this construction was proposed by Andraud of Paris (Fig. 36), and the arrangement, as indicated by his drawings, shows the superheater entirely within the firebox, and placed above the fire in the form of a coil. This arrangement seems to be more practicable than that which was proposed by a Scotch engineer, John Hasel, in 1852, in which he placed a similar coil in the bed of fuel; it did not provide, however, for protecting the tubes when there is no steam passing through the superheater formed by the coil.

Estrade, a Frenchman, in 1882 proposed the arrangement shown in Fig. 37. This scheme consisted of a superheater located

FIG. 36.



ANDRAUD SUPERHEATER, 1853, FIREBOX TYPE.

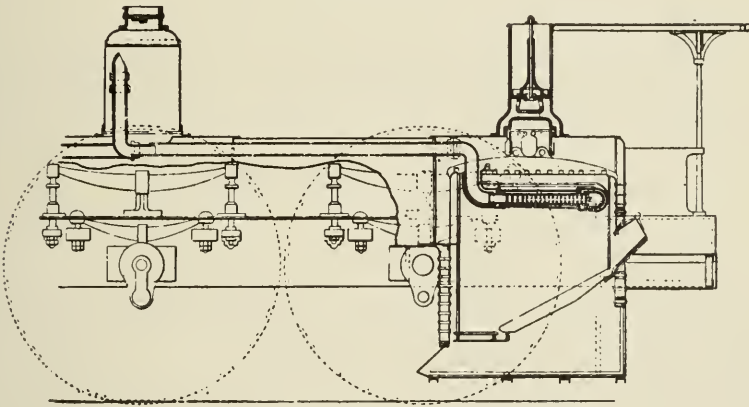
In this form the superheater has a coil of pipe in the firebox. No provision is made to protect the coil when no steam is flowing through it.

above the fire and immediately beneath the crown sheet of the boiler. The tubes conveying the steam were encased in an outer tube which was provided to protect them from excessive heat. The mechanical difficulties that have been mentioned as likely to occur in a boiler of this construction probably prevented its use.

For the same reason the construction proposed by Mossler & Stauffer in 1890 (see Fig. 38) never was applied to a locomotive. This arrangement, however, provides, in addition to the superheating heating surface in the firebox, a coil in the barrel of the boiler, and this coil made up the larger part of the water-heating surface for evaporation. A combination superheater of the fire tube and firebox type is shown in Fig. 39; this is an arrangement proposed by Schmidt in 1909. Here it is seen that the superheater elements are located in the fire tube, but instead of having a return wholly within the fire tubes, the

superheater is extended back and across the top of the firebox. This arrangement increases the length of passage of the steam within the superheater elements and at the same time subjects the elements to the much higher temperature of the firebox. A portion of the elements is protected by means of a brick arch baffle, shown directly beneath the tubes, and a chamber at the

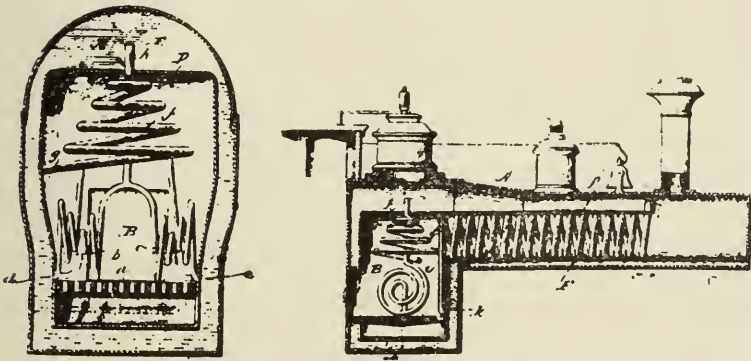
FIG. 37.



ESTRADE SUPERHEATER, 1882, FIREBOX TYPE.

This superheater shows a coil in the top of the firebox, but with a protective covering.

FIG. 38.



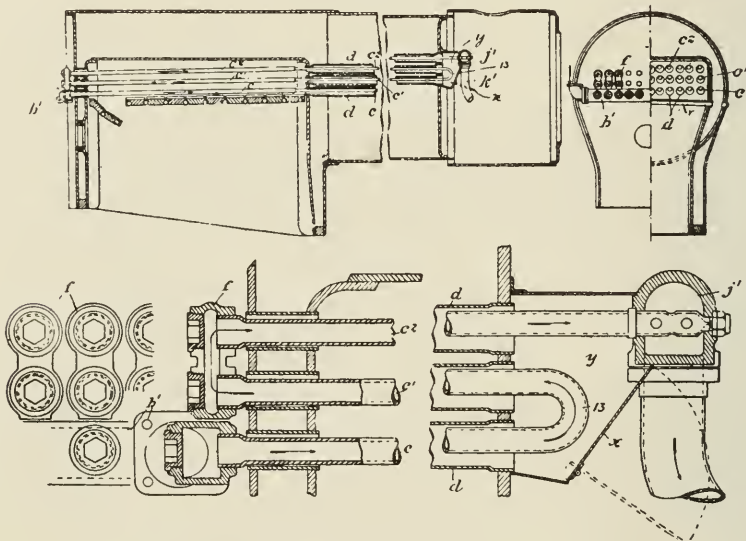
MOSSLER-STAUFFER SUPERHEATER, 1890, FIREBOX TYPE.

This superheater, which is merely a suggestion and was never used, provides superheating coils in the bed of fuel, above the bed of fuel and in the smoke flue.

front end provides for closing off the passage for gases through the large fire tubes containing the superheater elements when no steam is being used by the locomotive. It would seem that this arrangement should produce the highest degree of superheat with the least amount of heating surface. The scheme as proposed, however, provides for the collection of the superheated steam at the smokebox end of the superheater, and if such a collection

is made it is probable that there will be some loss in superheat in the passage of the steam from the firebox to the steam chest. If it would be possible to maintain the superheater tubes within the firebox, it would seem more logical to have the outlet for these elements at the firebox end of the boiler, the steam passing thence directly to the steam chest, rather than from the firebox

FIG. 39.



SCHMIDT SUPERHEATER, 1909, FIREBOX TYPE.

This superheater is a combination of the firebox and fire tube type. The superheater elements extend from end to end of the boiler, crossing the upper part of the firebox, where they are protected by the fire-brick covering.

to the smokebox and then into the steam chest. This course would undoubtedly prevent loss of some superheat, or an excess of superheating heating surface within the boiler tubes which is only available for superheating the steam after it has left the hot surfaces contained within the firebox.

PART II.

SUPERHEATER TESTS.

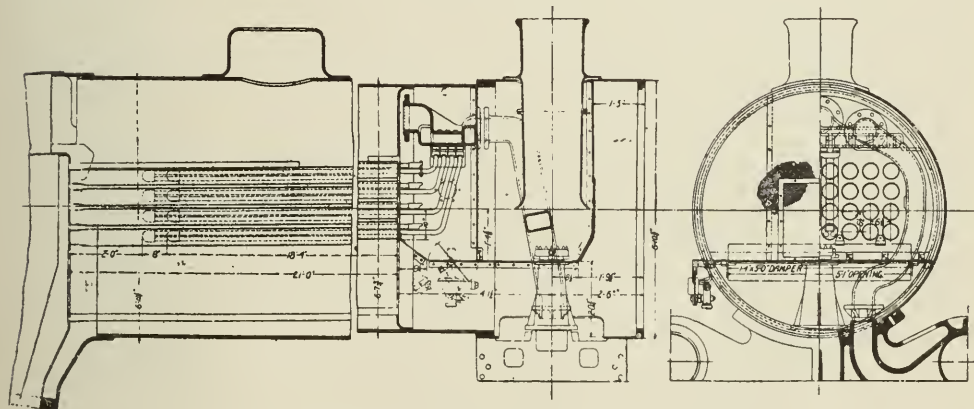
Having reviewed in outline the development of a practical form of locomotive superheater, it will be interesting to describe experiments with one of the fire tube type to determine the effect of superheat upon locomotive efficiency.

Before taking up the discussion of results, we should understand something of the form of the apparatus used and the method of conducting the tests.

The superheater used in all of the tests was a Schmidt superheater of the fire tube type, or an altered form of it. The normal, or what is called in this paper the standard superheater, consists of tubes arranged in groups or elements and located in large flues in the boiler. There were 32 elements in the locomotive used in the tests, one of the K2sa class of the Pennsylvania Railroad, and this standard superheater is shown in place in the boiler in Figs. 40 and 41.

Each superheater element is made up of four seamless steel tubes having an outside diameter of $1\frac{7}{16}$ inches and a thickness of 0.148 inch, all connected together by cast steel return

FIG. 40.



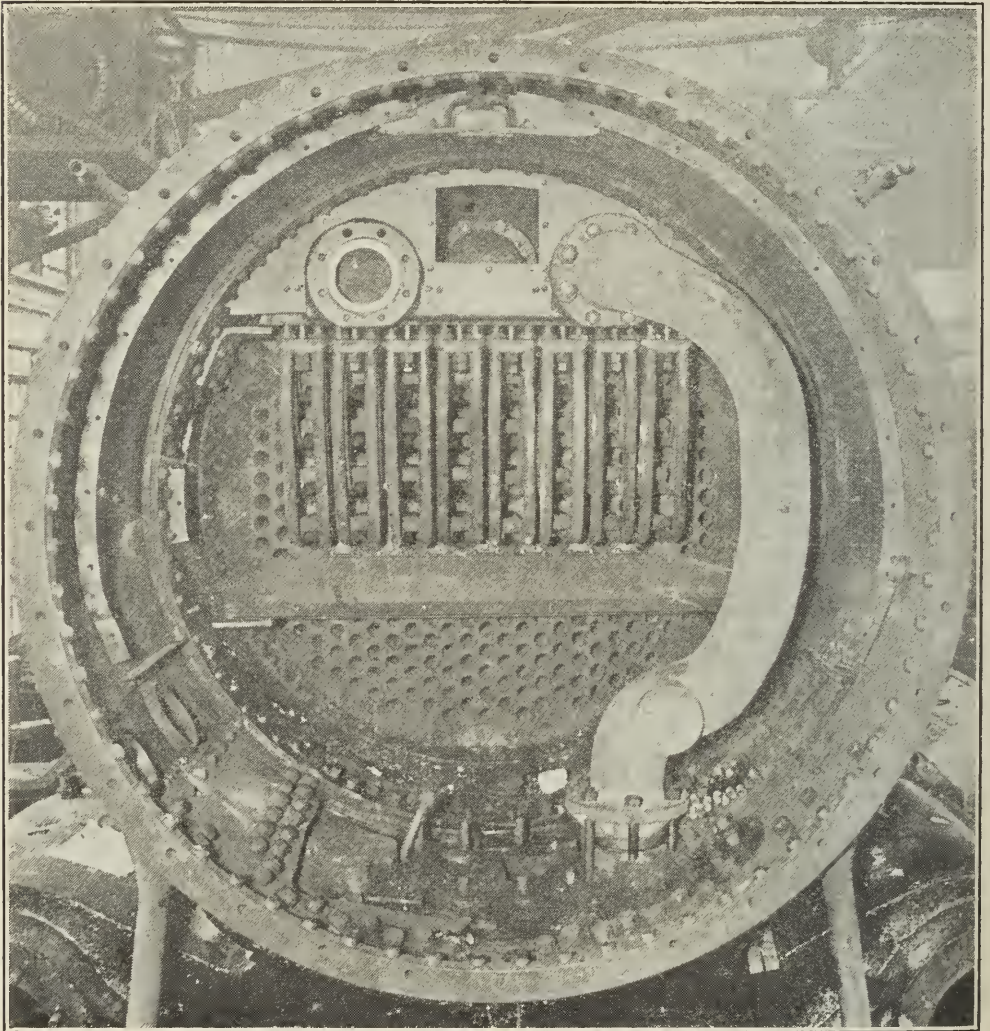
SUPERHEATER AND SMOKEBOX ARRANGEMENT.

The regular or standard Schmidt fire tube superheater, as applied to the boiler of the test locomotive. This locomotive has steam pipes inside of the smokebox. A later form has outside steam pipes which extend through the smokebox sides and connect directly with the steam chest.

bends to form a continuous tube or loop. The steam from the boiler enters the header in the smokebox, then flows into one of each of the thirty-two superheater elements, passing twice through the hot gases which surround the elements; that is to say, the steam flows to the firebox end of the boiler and then returns to the smokebox end and again flows back to the firebox end and finally to the superheater header, entering a part of the header partitioned off to receive superheated steam. The steam then passes directly to the cylinders. This and similar arrangements are called in this paper "two-pass" superheaters. The superheater elements are connected to the header by a ball-joint connection, the ends of each element being drawn up to the header and held in place by a single bolt.

To protect the elements of the superheater from overheating when there is no steam flowing through them, an automatic damper is provided in the smokebox, as shown in Fig. 40. This damper opens only when steam is flowing through the super-

FIG. 41.

SUPERHEATER AND STEAM PIPES, K2S_a LOCOMOTIVE.

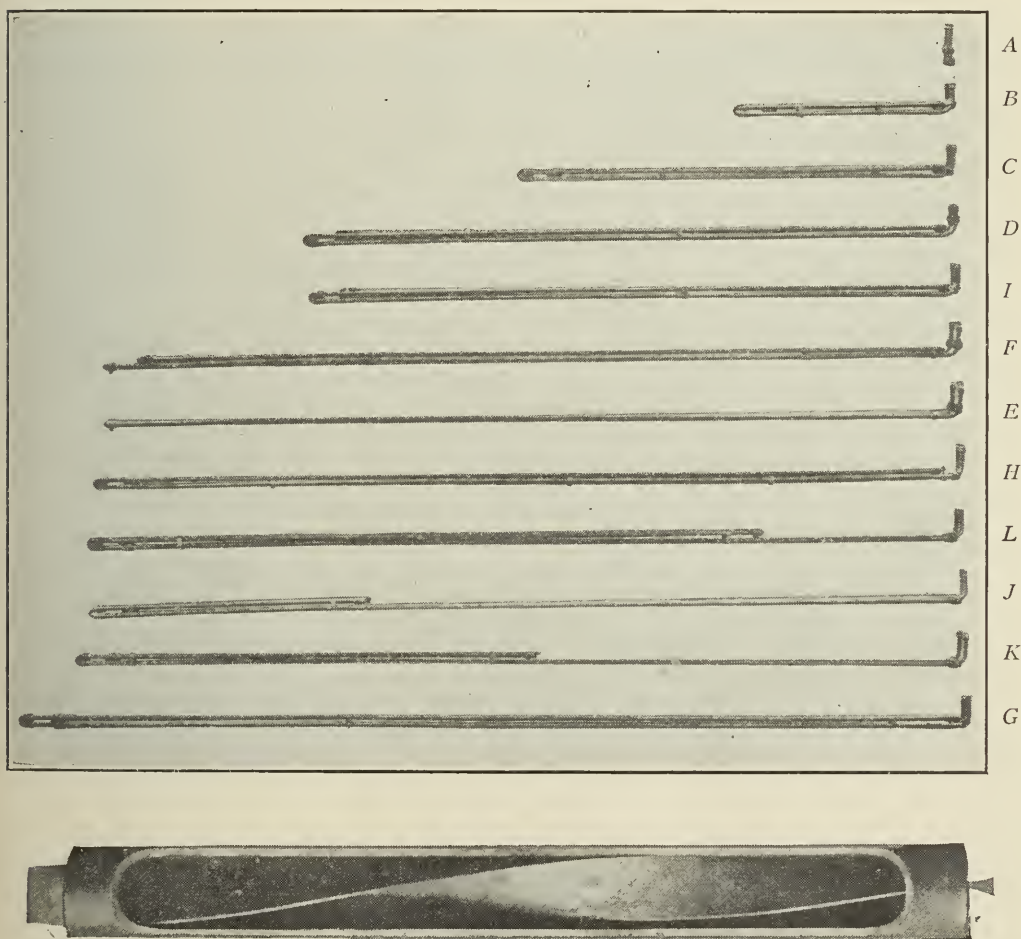
The standard superheater is shown in place. The deflector plates, damper, netting and a steam pipe have been removed.

heater, the steam pressure in the steam chest operating the damper piston.

At the firebox end the elements are supported by short lugs, the purpose of which is to raise the elements from the bottom of the flue so that the gases have a passage underneath.

The superheater elements take up a large part of the available space in the boiler flue, presenting a partial obstruction to the passage of the products of combustion through the flue, and the cinders in consequence accumulate about the elements, so that the flues must be cleaned at frequent intervals.

FIG. 42.



SUPERHEATER ELEMENTS.

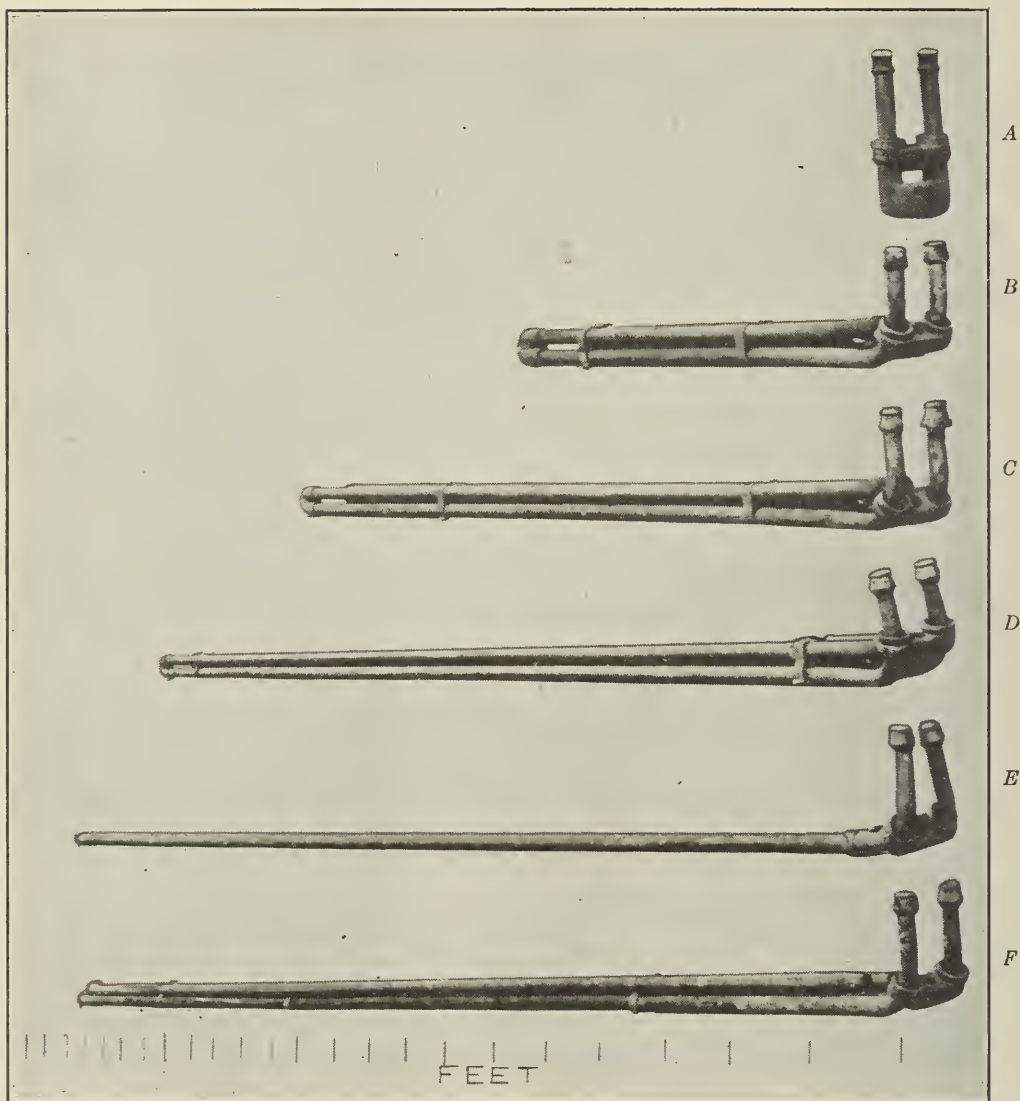
This view shows one element of each of the superheaters and indicates their relative length.

The enlarged view of a superheater tube shows a spiral or twisted plate which extended the whole length of each tube. This arrangement was used in Superheater I, one of the double-pass, $\frac{3}{4}$ -length superheaters.

The superheater flues in the boiler have an outside diameter of $5\frac{1}{2}$ inches at the front tube sheet, and for all of that portion through which the elements extend. Near the firebox tube sheet the flues are swaged down to an outside diameter of $4\frac{1}{2}$ inches, this reduction being for the double purpose of permitting an

unrestricted circulation of water near the tube sheet, and also so that the fire area or flue opening at this point may be about equal to the opening for gases in the part of the tube containing

FIG. 43.



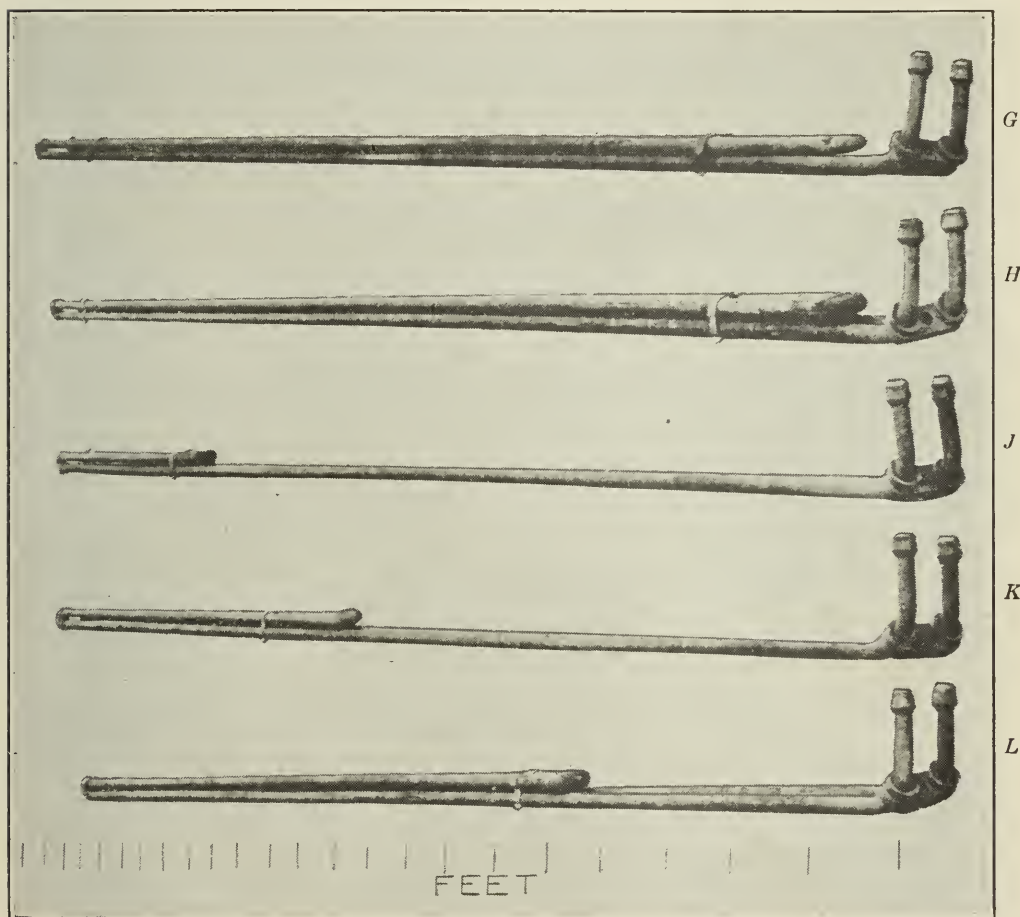
SUPERHEATER ELEMENTS.

Special or altered forms. *A*, short returns at header; *B*, $\frac{1}{4}$ length, 4 feet long; *C*, $\frac{1}{2}$ length, 9 feet long; *D*, $\frac{3}{4}$ length, 14 feet long; *E*, single pass, 19 feet long; *F*, single pass dummy returns, 19 feet long.

the superheater element. The standard form of the superheater has 32 elements and a heating surface, including the header, of 989.3 square feet. The standard superheater is shown assembled in Figs. 40 and 41, and one element of it at *H* in Figs. 42 and 44.

In order to obtain different degrees of superheat without in any way changing the water-heating surface of the boiler or the engine conditions, different forms of superheater elements were used, maintaining the same superheater header and large flues. Fig. 42 shows the relative size of the different arrange-

FIG. 44.



SUPERHEATER ELEMENTS.

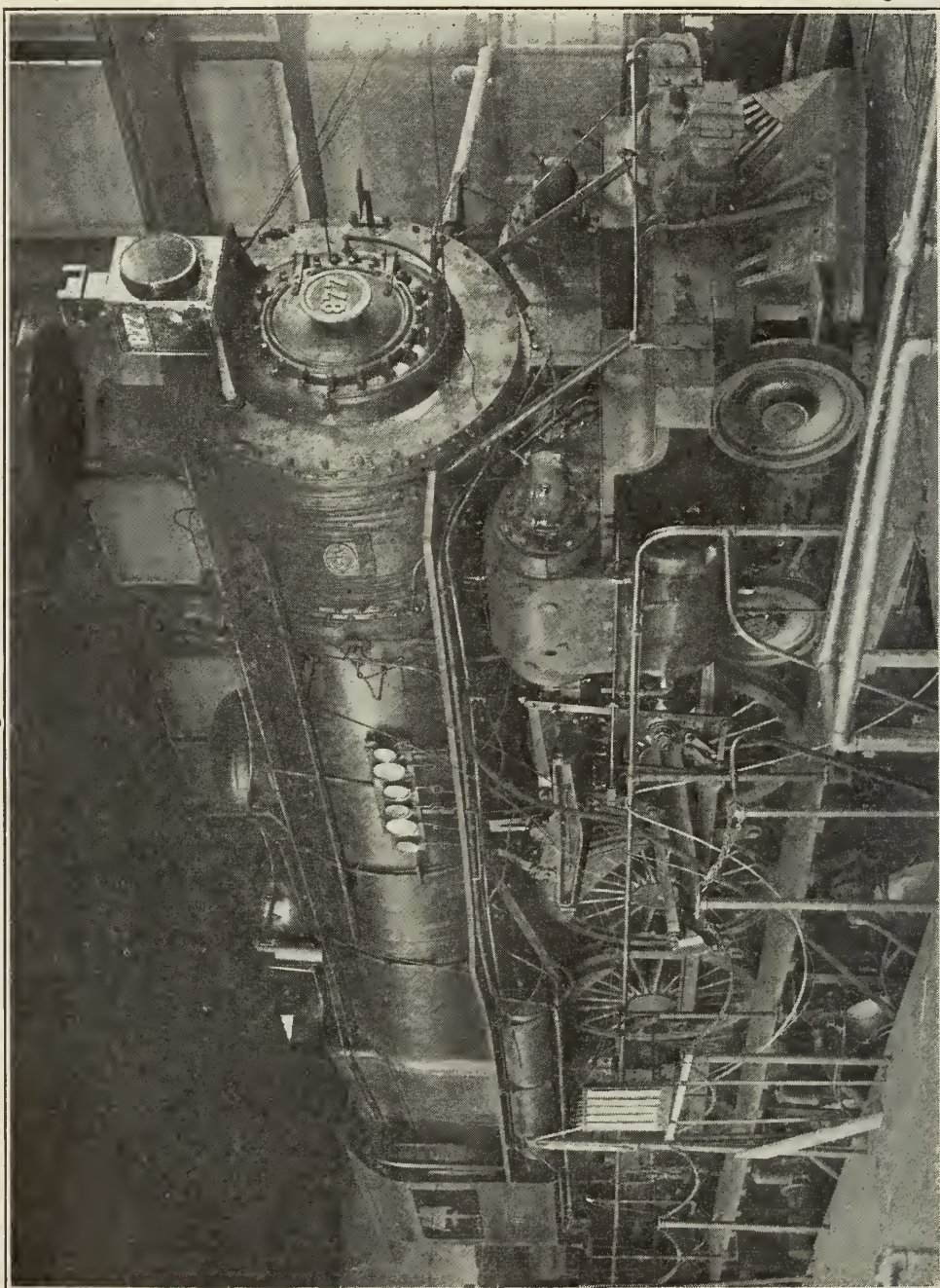
The standard and special or altered forms. *G*, extra length, 20 feet 5 inches long; *H*, standard, 19 feet long; *J*, $\frac{1}{4}$ return, 19 feet long; *K*, $\frac{1}{2}$ return, 19 feet long; *L*, $\frac{3}{4}$ return, 19 feet long.

ments, while in Figs. 43 and 44 the details of the arrangements are clearly indicated.

In Fig. 43, *A* is simply an element at the header of which it might be said that when all of the elements are in place they form a smokebox superheater. *B* is a quarter-length superheater.

The superheater *C* is one-half length and *D* three-quarter length. *E* and *F* are of the same length as the standard, but of one pass.

FIG. 45.



LOCOMOTIVE NO. 877, CLASS K2sa, IN POSITION FOR TEST.

Locomotive Test Plant, Pennsylvania Railroad Company, Altoona, Penna. The locomotive used in the superheater tests.

F, however, has additional pipes representing the second pass, but having no steam flowing through them. These dummy pipes were used with this single-pass superheater to make the gas

passage around the elements the same as with the standard arrangement. In Fig. 44, *G* is arranged in the same way as the standard, except that it is 17 inches longer for both passes, whereas *J*, *K* and *L* are similar to the standard arrangement *H*, excepting the return portion, which has a length one-quarter, one-half, and three-quarters that of the corresponding part of the standard superheater.

In addition to the foregoing, Fig. 42 shows a detail of a superheater of the three-quarter length arrangement of double-pass superheater, which had twisted plates inserted in the tubes of the superheater elements, the object being to cause a whirling motion of the steam so that its heat-absorbing action might be improved. An element is shown at *I* in Fig. 42.

DESCRIPTION OF LOCOMOTIVE.

One locomotive was used for all of the superheater tests; it was a class K2sa Pacific type passenger locomotive of the Pennsylvania Railroad with a brick arch in the firebox. This locomotive is shown in Fig. 45.

The general dimensions of the locomotive when equipped with its regular or standard superheater are given below.

Total weight in working order, lbs.	293,200
Weight on drivers in working order, lbs.	179,900
Cylinders (simple), inches	24 x 26
Diameter of driving wheels, inches	80
Heating surface in tubes (water side), sq. ft.	3436.37
Firebox heating surface, sq. ft., including arch tubes.....	208.02
Heating surface of superheater, fireside (standard).....	989.32
Total heating surface (based on water side of tubes), including superheater, sq. ft.	4633.71
Total heating surface (based on fire side of tubes), in- cluding superheater, sq. ft.	4312.40
Grate area, sq. ft.	53.72
Boiler pressure, lbs. per sq. in.	205
Valves, type.....	12 in. piston
Valve, motion	Walschaerts
Firebox type	Wide, Belpaire
Number of tubes	202
Number of flues (superheater)	32
Outside diameter of tubes, inches	2.25
Outside diameter of flues, inches	5.5
Length of tubes, inches	250.08

A complete efficiency test of this locomotive, when equipped with the standard form of the Schmidt superheater, was made before the special superheater tests were undertaken and the results are given in full in Bulletin No. 18, "Tests of a Class K2sa Locomotive,"¹ where a further description and drawings of the locomotive are shown.

METHOD OF CONDUCTING TESTS.

With each of the superheater arrangements, where it was possible, six tests were run, each having a length of one hour and a half; the cut-offs being 15, 25, 35, 45 and 50 per cent., except where the longer cut-offs could not be maintained. With some of the superheaters one test was made at a speed of 120 r.p.m. or 28 m.p.h., while all of the other tests were made at a speed of 240 r.p.m. or 57 m.p.h., thus the variable of speed of the locomotive was largely eliminated, and it may be generally assumed that the tests were all made at 57 m.p.h. The steam temperature was measured by means of a mercury thermometer inserted in a well in the steam passage of the cylinder saddle, at a point where the steam is entering the steam chest. The steam pressure was observed at this point and at the dome of the boiler by means of steam gages.

During the course of the tests the superheater elements were very carefully blown out with air at the end of each day, so that the conditions as to the superheater heating surfaces were apparently uniform and good.

While the tests were of one hour and a half in length, they have been recorded in the tables to appear as two tests, one of an hour duration and one of an hour and a half. It will be noted that the average for the latter part of the test or the last 60 minutes is, in most cases, slightly higher than for the longer time, for the steam temperature and superheat tend to rise slowly for perhaps three-quarters of an hour after the start of the locomotive (see graphical logs of tests, Figs. 55 and 56, for illustration of this effect). This effect may be due to the condition of the fire. The firebox temperature appears to increase during the whole time of a test run. At any rate, the results for

¹ Copies of this bulletin may be had upon application to the General Superintendent of Motive Power of the Pennsylvania Railroad, Altoona, Pa.

the latter part of the total time have been used in plotting all of the diagrams in the paper.

With the complete superheaters such as the standard, the half-return, etc., the superheat, a few minutes after starting, is high. Referring to the graphical log for test No. 3300.91, Fig. 56, the superheat at the beginning of the test is 228 degrees and it increased only 26 degrees during the one and one-half hours of running. In test No. 3300.50, with the half-return superheater, the superheat at starting is 240 degrees, increasing 38 degrees to a superheat of 278 degrees at the end of 90 minutes of running.

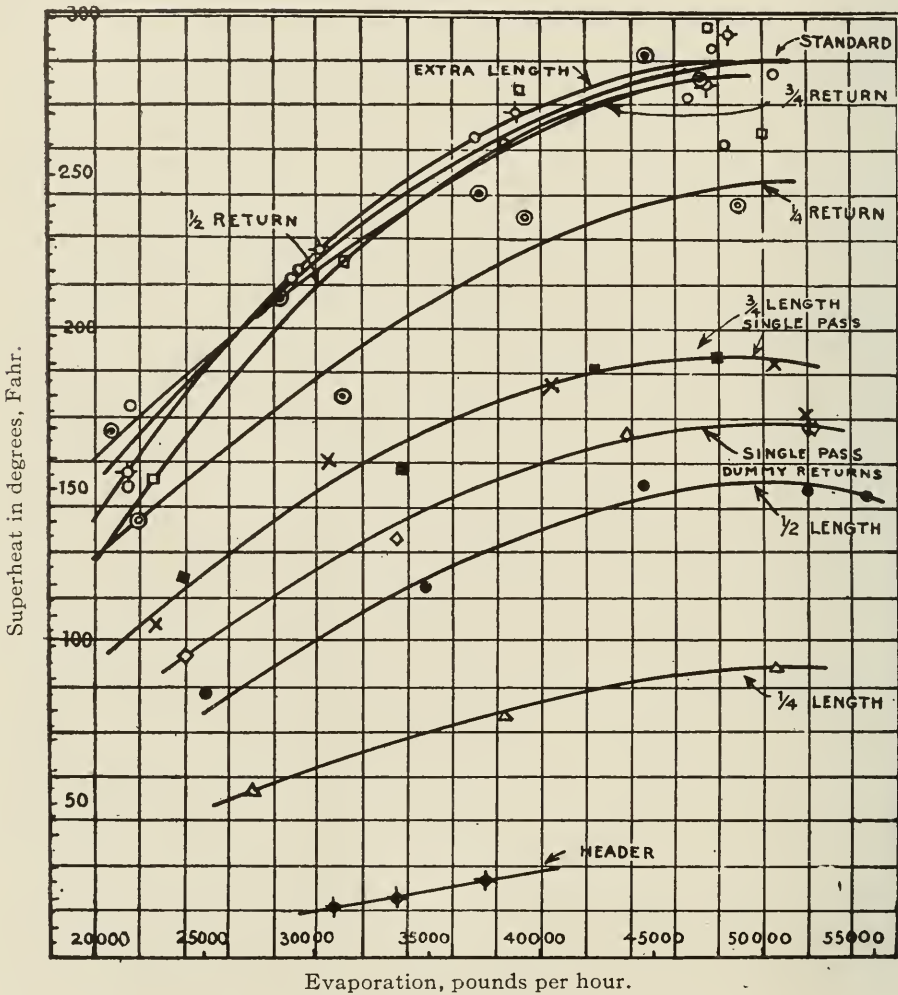
It was to obtain a range of superheat that the several superheater arrangements, full-length, three-quarter, one-half, one-quarter length and the short returns at header, were tried out. It was not expected that the shortened superheaters would develop an arrangement suitable or desirable for use in regular service; the only purpose in using them was to obtain wide variations in superheat.

RESULTS OF TESTS.

The Effect of Different Degrees of Superheat.—The evaporation and superheat for all of the superheater arrangements are shown in Fig. 46, and an evaporation between 21,000 and 55,000 pounds per hour was obtained, the superheater consisting of short returns at the header, and having a heating surface of about 50 square feet as compared with the standard, which has a heating surface of nearly 1000 feet, evaporates about 31,000 pounds of water per hour, and has an indicated horse-power of 1425, where, with the same cut-off and one of the extra-length superheaters, the evaporation is only about 21,000 pounds for this indicated horse-power. This effect is caused by the small superheat obtained with the short returns, requiring a greater weight of steam for the power produced. We find further that this small superheater will not evaporate more than 37,600 pounds per hour or but 70 per cent. of what the half-length superheater is capable. The small capacity of this header superheater is brought about by the fact that it does not extend into the large flues in the boiler. With these large flues open or unobstructed by the superheater elements, the boiler does not steam properly, the draft action is unchecked, and holes are made in the fire by the violent agitation of the draft. With the standard steam boiler, having all of the tubes of a small size or with the superheater

boiler having the superheater elements in the large flues, the draft pulsations are smoothed out and the fire is not so violently agitated. The small superheater gives a maximum superheat of but 26° .

FIG. 46.



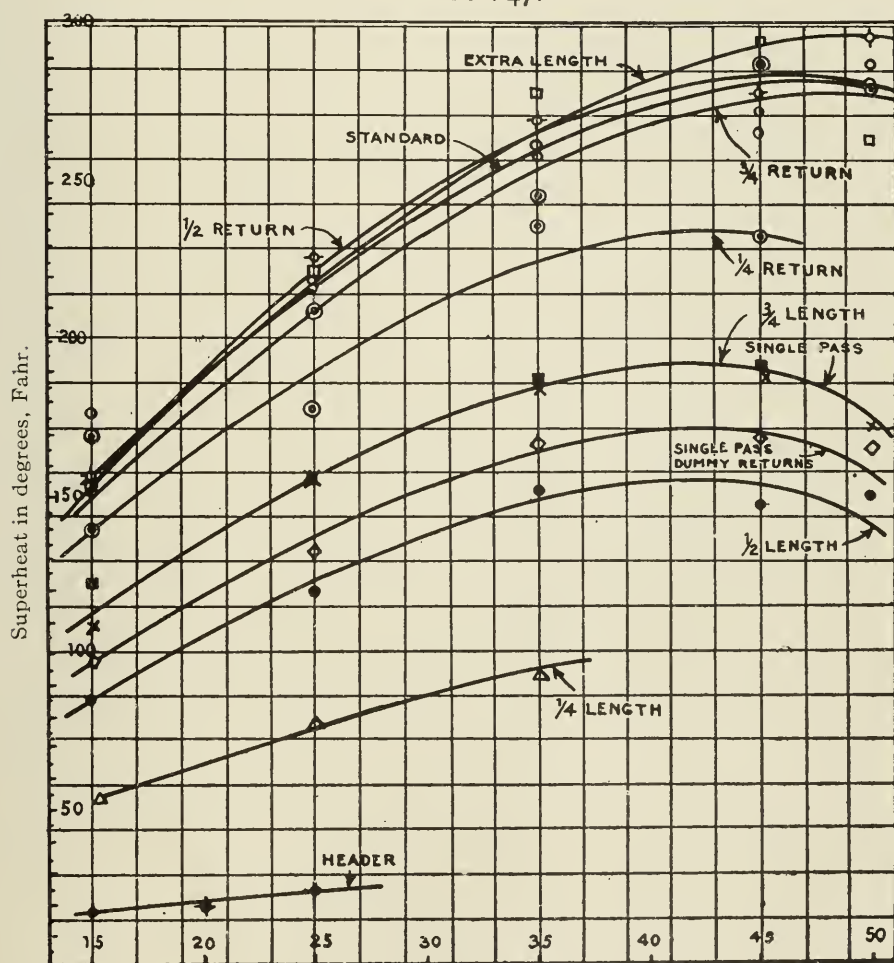
SUPERHEAT AND EVAPORATION

The superheat increases with an increase in evaporation up to about 50,000 pounds per hour. Above this evaporation there appears to be a falling off in superheat, probably due to the heavy fire that must be carried, and the fact that all of the coal fired is not being burned.

The superheaters of one-quarter, one-half, and three-quarter length show a regular increase in superheat produced, with the increase in length of superheater. The one-quarter length produces a maximum superheat of 90° and the three-quarter length a maximum of 190° . It is also shown by Fig. 46 that as the superheat is increased, the evaporation, when running at a short

cut-off, is decreased, and further, that the one-half length superheater gives the greatest evaporation that was obtained with any of the superheaters, about 55,000 pounds per hour. There would seem to be a best superheater length or area for maximum evaporation, but it must not be understood that this superheater, which is best for evaporation, gives the maximum horse-power.

FIG. 47.



Cut-off in per cent. of stroke.

SUPERHEAT AND CUT-OFF.

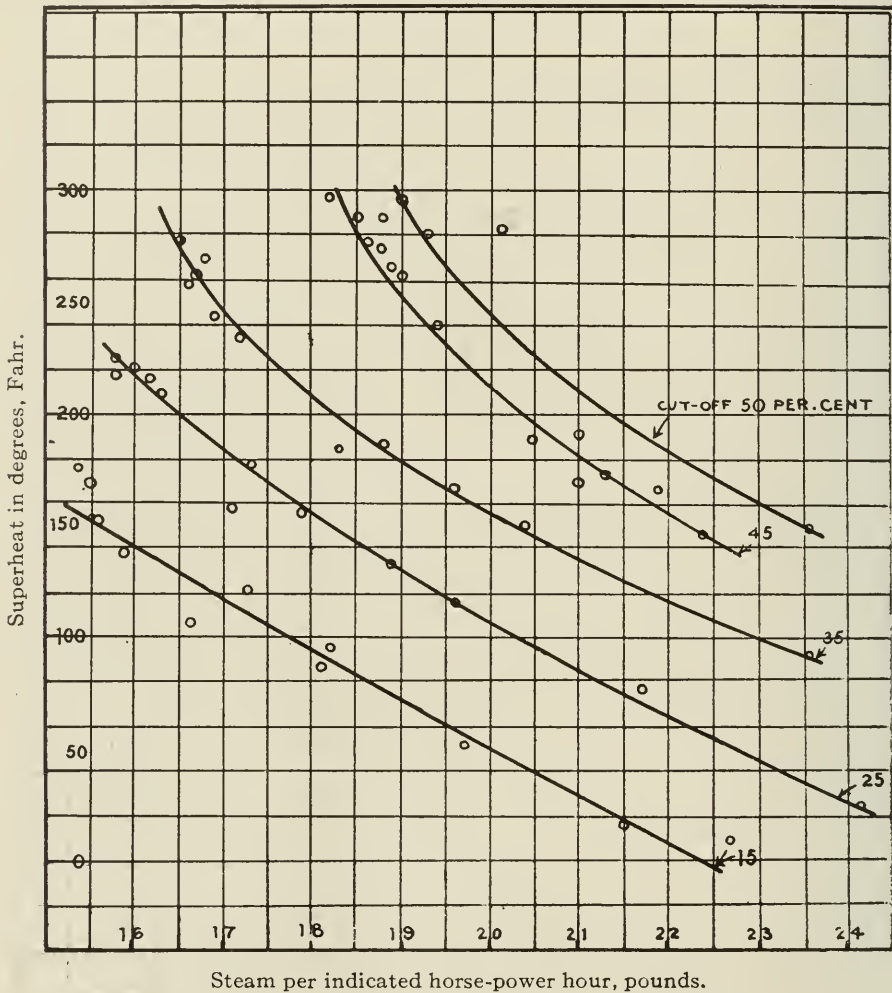
The superheat increases with the cut-off up to 45 per cent.; beyond 45 per cent. there is a falling off in superheat. (See Fig. 48.)

The extra length shows a higher superheat than the standard length, but there might be difficulties in the use of this long superheater where the ends come within a few inches on the firebox end of the flue, and the one-half return gives fully as much superheat; there would seem to be no advantage in the

extra length, with the disadvantage of increased friction due to the longer steam passage.

Referring now to Fig. 47, which shows superheat and cut-off, we find that the superheaters arrange themselves in very nearly

FIG. 48.



CUT-OFF AND STEAM PER INDICATED HORSE-POWER.

At the shorter cut-offs there is a uniform decrease in the water rate with each increase in superheat. As the cut-off is extended the water rate increases, but has a tendency to become more nearly constant with an increase in superheat. A water rate of 24 pounds is obtained with a superheat of about 30 degrees. If the superheat is increased to 220 degrees without a change in cut-off, the water rate is reduced to 16 pounds.

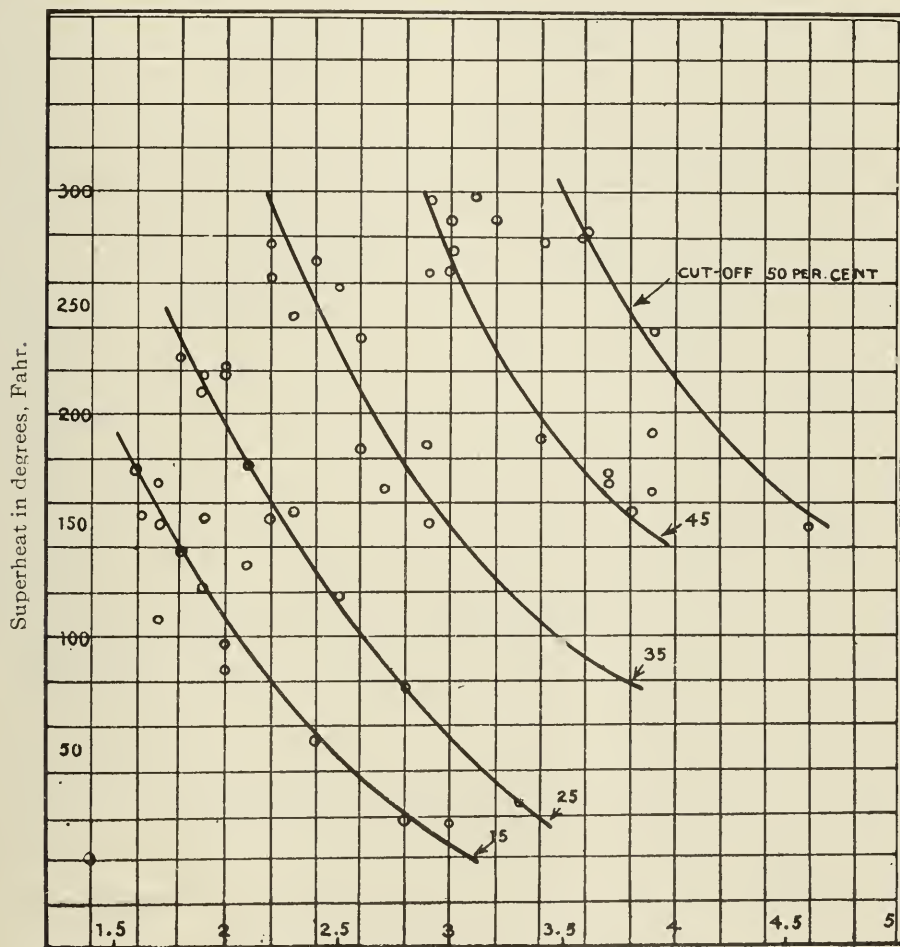
the same way as in Fig. 46, and this is to be expected because, on account of the constant speed, the evaporation is dependent almost entirely on the length of cut-off.

Considering now the economy resulting from the superheat we have in Fig. 48 the cut-off and steam per indicated horse-

power. This diagram expresses graphically the essential facts for which the experiments were made, and gives for the first time authentic data upon the economy due to superheat unobscured by other variables.

The points of this diagram do not indicate the arrangement of superheater, but show the effect of both the superheat and

FIG. 49.



Coal per indicated horse-power hour, pounds.

SUPERHEAT AND COAL PER HORSE-POWER.

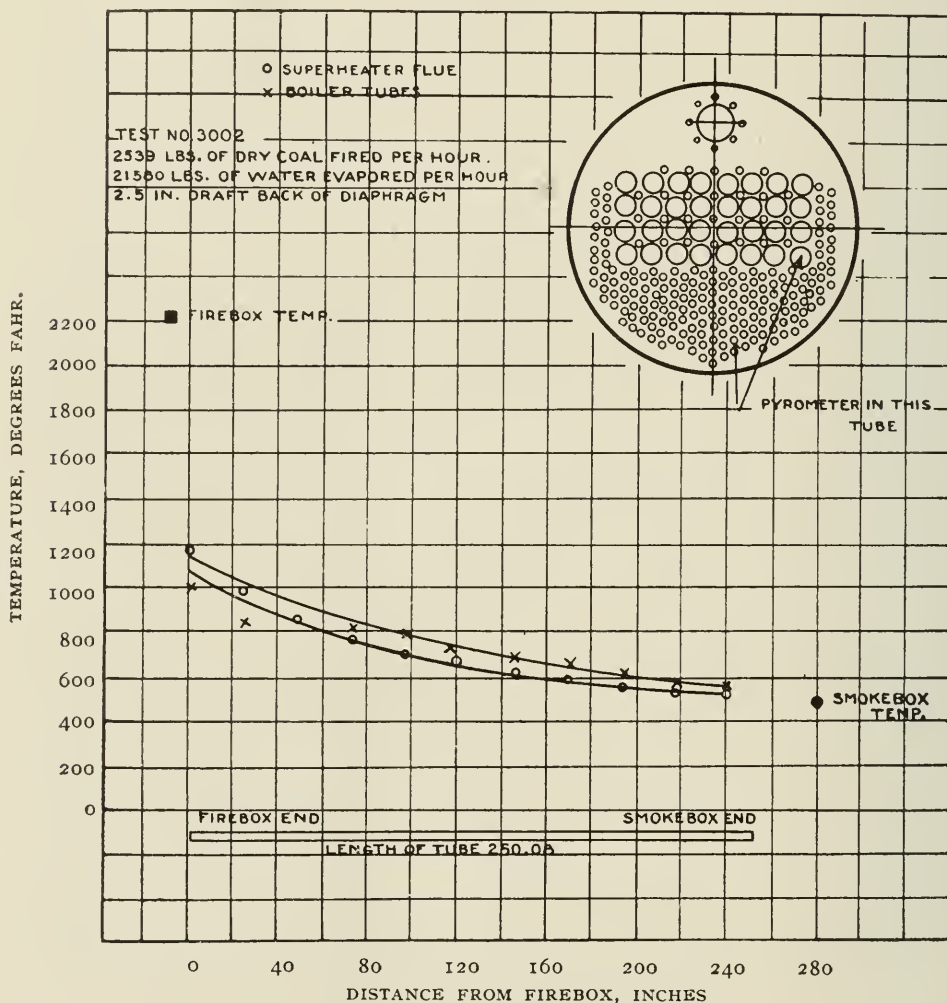
Each increase in superheat shows a saving in coal.

cut-off on the economy in steam. We find from the diagram, which shows a superheat ranging from zero, or practically saturated steam, up to 300° , that for every increase in superheat, at every cut-off, there is a saving in steam, and that at 15 per cent. cut-off, at the speed of these tests, for every 20 degrees rise in superheat there is a reduction in water rate of one pound

per indicated horse-power hour. At 50 per cent. cut-off this increases to a requirement of about 40° rise for the same reduction in water rate.

With a cut-off of 15 per cent. and a superheat of about 70° we can obtain a water rate of 19 pounds per indicated horse-

FIG. 50.



TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

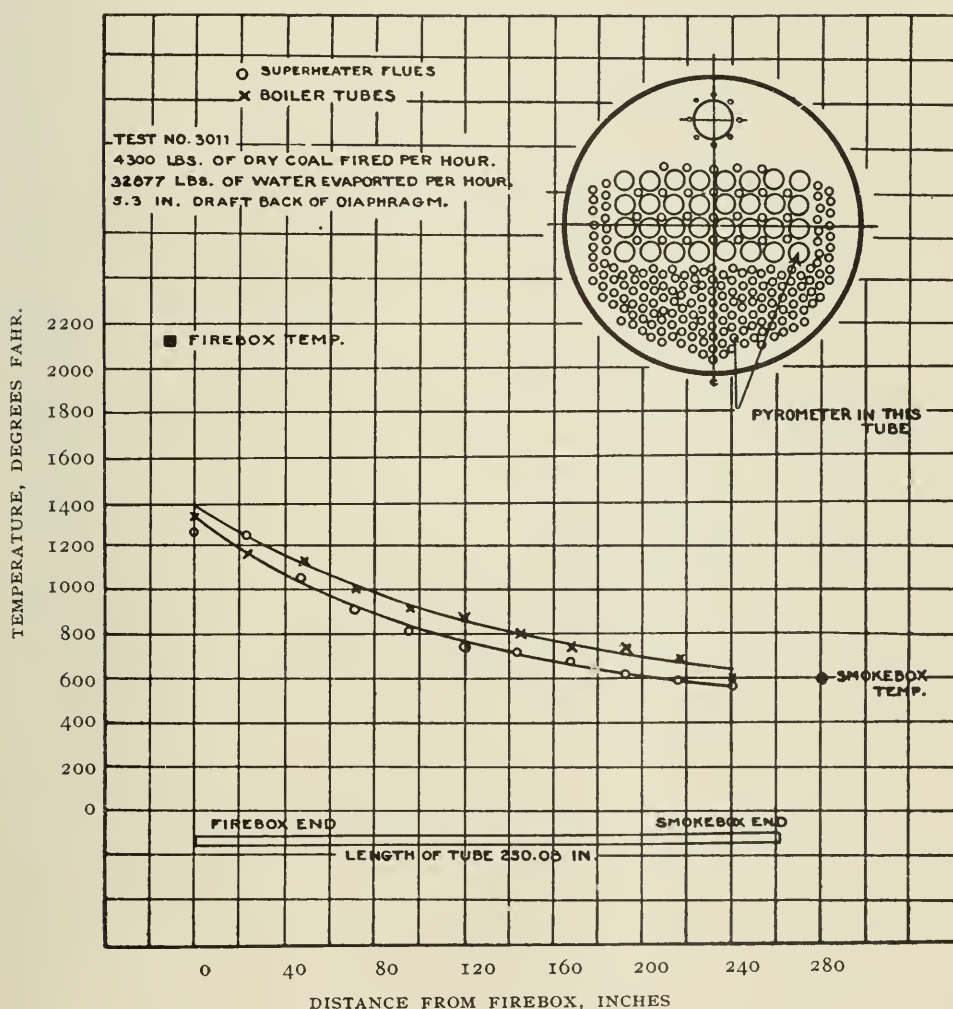
Temperatures at a coal rate of 2539 pounds per hour. The steam temperature is 572 degrees and is equal to the gas temperature at a point 170 inches from the firebox.

power hour, while if the cut-off is extended to 50 per cent. at the same speed, the superheat must be increased to 300 degrees so that the water rate will remain at 19 pounds. The very great importance of the length of cut-off is thus apparent, but even with the longest cut-off that is shown the water rate does not reach 24 pounds, or what may be called the minimum water rate for

saturated steam. It thus appears that superheat always shows a saving in steam if the cut-off does not exceed 50 per cent. Very similar conclusions may be drawn from Fig. 49, which shows the superheat, the cut-off and coal per horse-power hour.

Some time before these superheater tests were undertaken a

FIG. 51.



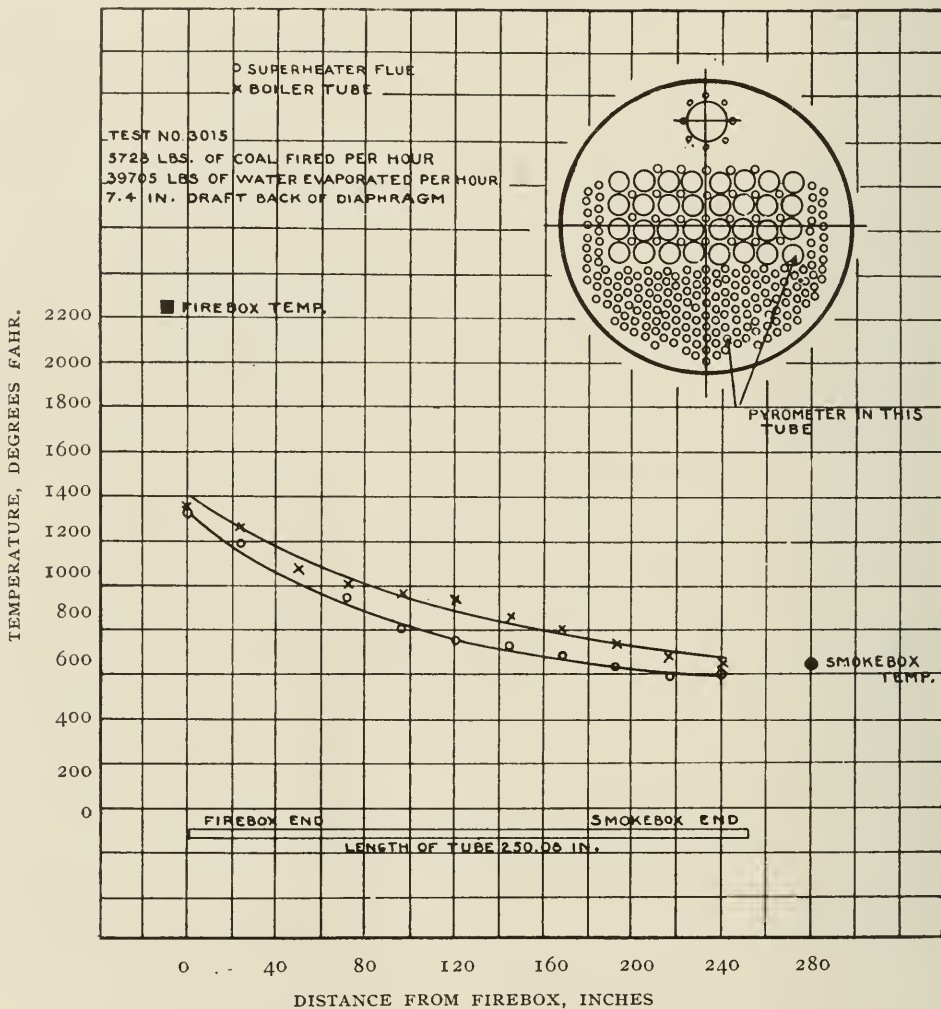
TEMPERATURE IN THE SUPERHEATER FLUE AND BOILER TUBE.

Temperatures at a coal burning rate of 4300 pounds. The steam temperature is 633 degrees and is equal to the flue temperature at a distance of 180 inches from the firebox.

series of efficiency tests with the standard superheater was made with this locomotive, and Figs. 50 to 52 show the temperature measurements in boiler tube and superheater flue made at that time. In Fig. 50 the temperature in the superheater flue is 1160° at the firebox end, falling to about 540° at the smokebox end.

The steam temperature for this test is 572° . It will thus be seen that at about 170 inches from the firebox the steam temperature equals the temperature of the gases, and there would be no gain by extending the superheater return any distance forward of this point. This return portion extends forward to a point 148 inches

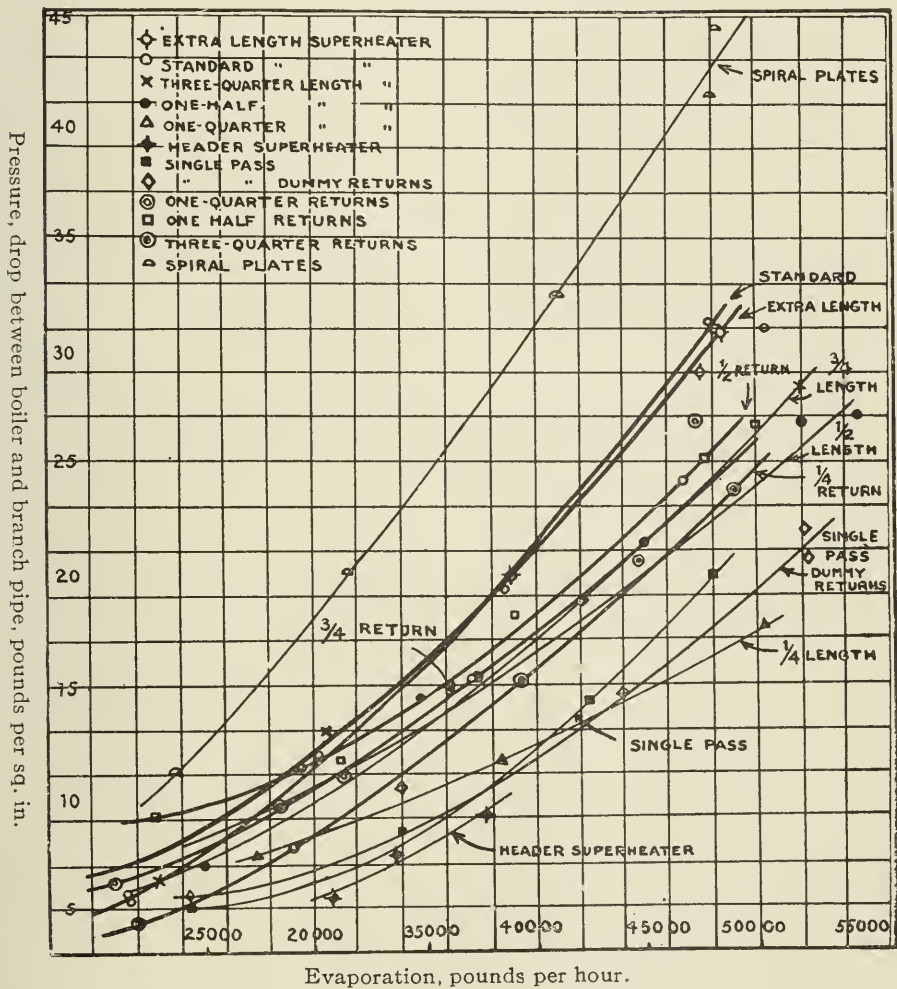
FIG. 52.



from the firebox. Figs. 51 and 52 show very similar results in regard to the point where the steam temperature becomes as high as gas temperature. From a consideration of these temperature curves, one reason for the good results by the use of the half-return superheater is made clear.

There is a loss in steam pressure as the steam flows from the boiler through the superheater to the steam chest, and this loss in pressure is shown graphically in Fig. 53. All of the superheaters are shown on this diagram. As would be expected, the superheater having the spiral plates in the tubes shows the

FIG. 53.



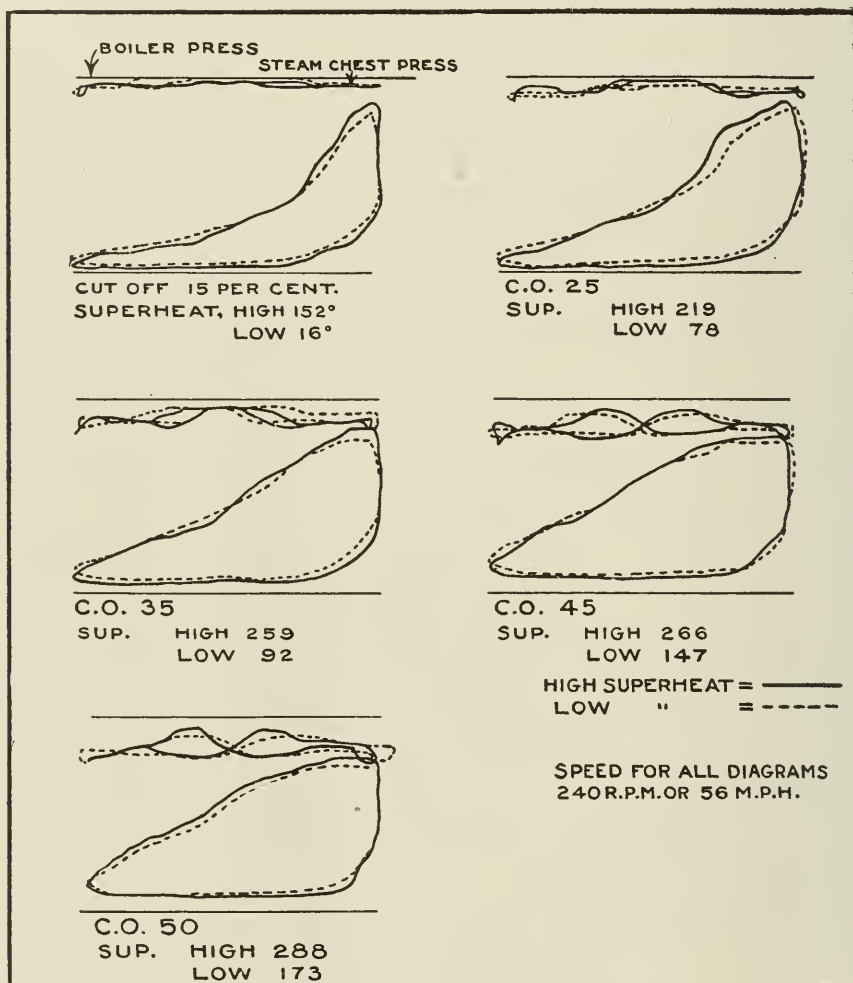
The superheater with spiral plates in the tubes shows the greatest loss in pressure, while the short superheater consisting of short returns at the header shows the least loss.

largest loss in steam pressure as the steam flows through the superheater. These plates have a retarding effect, and, as we have shown in other diagrams, the increase in superheat obtained by their use does not overcome the loss in power due to the pressure drop. The short returns show the least drop in pressure, as is to be expected, the passage through the superheater in this

case being 25 inches in length. The single-pass superheater shows a little greater drop in pressure, it having a length of 497 inches.

Indicator diagrams for high and low superheat are shown in Fig. 54. The first of these diagrams is for a cut-off of 15 per cent. In one case the superheat is 152° and in the other 16° , or

FIG. 54.



INDICATOR DIAGRAMS SHOWING HIGH AND LOW SUPERHEAT.

The greater fluidity of the highly superheated steam is shown by the high initial and low back pressure.

a difference of 136° . There is a drop in pressure between the boiler and steam chest of about 8 pounds. The dotted lines are for steam with a low superheat and the full lines for steam with high superheat. During the admission to the cylinder, the steam having a low superheat shows the lowest pressure during the

whole period of admission. During expansion, however, the pressure for the steam of low superheat is higher than for the highly superheated steam. During the return stroke of the piston, while the steam is flowing out of the cylinder, the steam having a low superheat shows a higher back pressure than the highly superheated steam. The same characteristics are evident on all of the diagrams, and the indications are that the highly superheated steam is more fluid or flows more freely into and out of the cylinder than does the steam of low superheat. It was not possible to make a direct comparison of highly superheated and saturated steam, but there are large differences in the superheat in each pair of diagrams.

The results of the tests show conclusively that there is an almost direct relationship between the economy in water and fuel and the degree of superheat, within the range of the experiments. It would be interesting to know how far this general law holds true for a given economical working cut-off. It is seen that if the superheat, at a short cut-off, could be obtained as high as that which was obtained for a long cut-off, economies more remarkable than are shown, in steam per indicated horse-power hour, would no doubt have been possible. The desirability, therefore, of high-degree superheating for locomotive practice cannot be questioned. Other deductions may be drawn from these tests which, summarized, may be expressed as follows:

(a) The standard superheater now in general use is found to give very satisfactory results with a possibility that some of the return portion could be eliminated with no detriment to the superheat obtained, and with an advantage in cost of material.

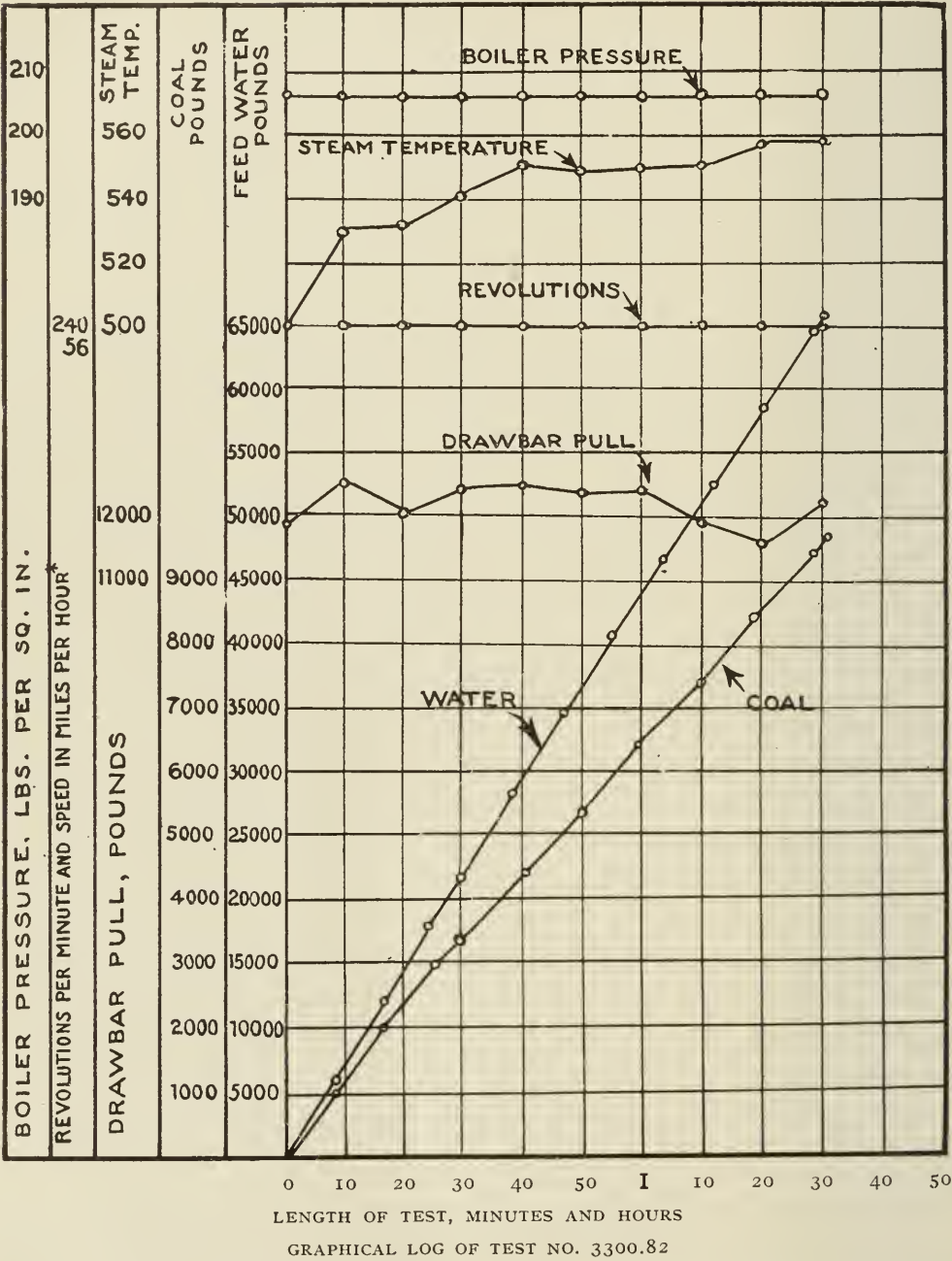
(b) Too much importance cannot be attached to the length of superheater; it must extend as far toward the fire as practicable limitations will allow, considering the life of the elements in the hot gases.

(c) There is an advantage in the return portion of the superheater, but this part may be shortened; to what extent has not yet been finally determined.

(d) As the superheat is reduced, the evaporation of the boiler is increased within certain limits; in other words, a boiler without superheater shows a larger maximum evaporation than one with a superheater. The power of the locomotive, however,

does not increase with the greater weight of steam produced; on the contrary, the power is reduced with the reduction in superheat.

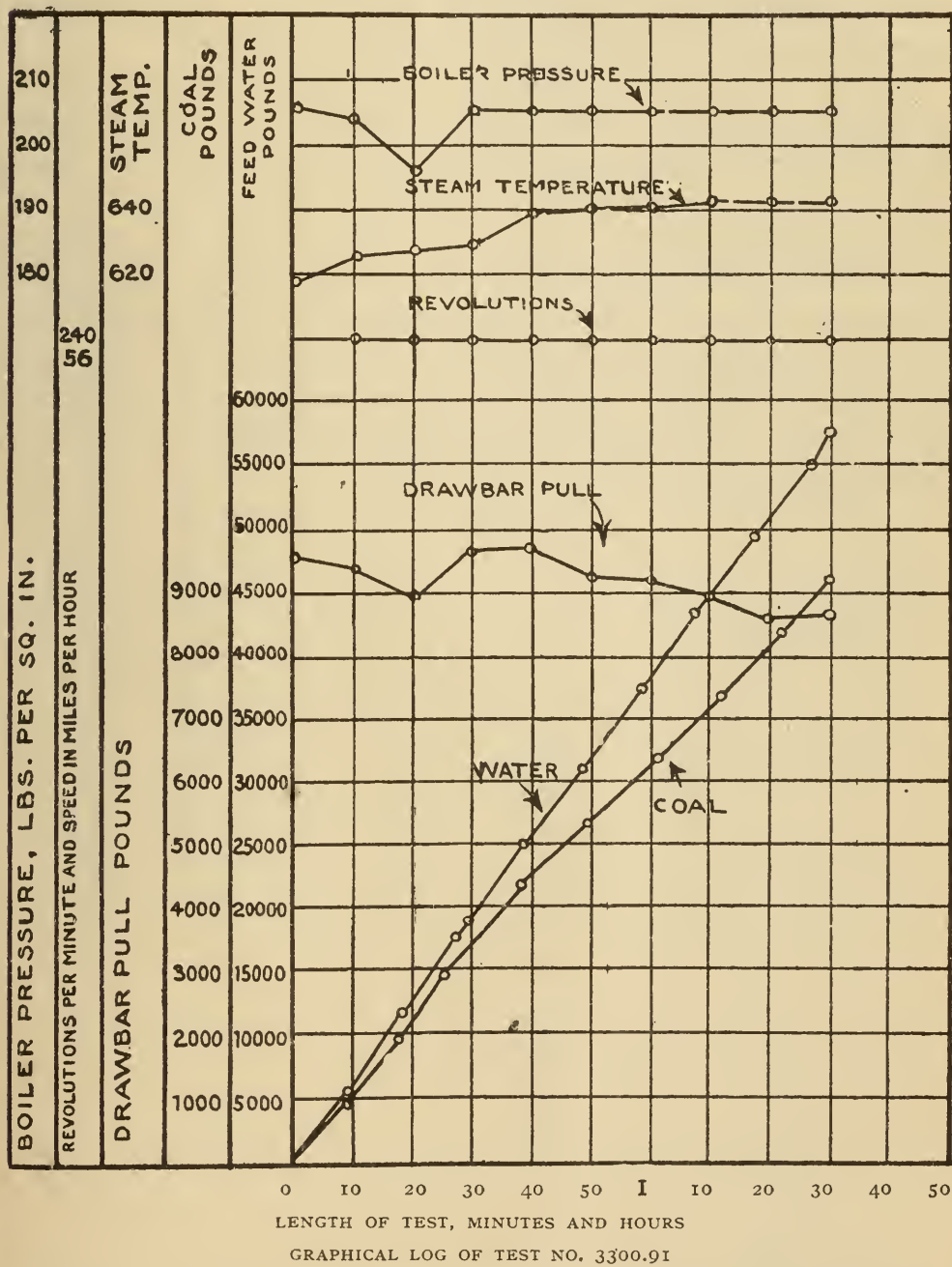
FIG. 55.



(e) Within the limitations of these tests, the highest superheat does not result in the lowest water rate; this is on account of the fact that to obtain the highest superheat the locomotive

may be run at an excessively long cut-off, the long cut-off increasing the water rate to a greater extent than is compensated for by the increase in superheat.

FIG. 56.



Applying now the knowledge obtained from these tests to locomotive practice, it is seen that the advantage of superheating may be utilized in two ways: either in coal and water saved, due

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to a reduced water rate, or by burning the same amount of coal as would be required in the boiler where it is generating saturated steam and obtaining a decided increase in the power output of the locomotive. If we exclude conditions of starting, this would permit superheater locomotives to haul heavier trains with an attendant saving in transportation facilities and labor.

There is another advantage in superheating which only recently is being given consideration, namely, by the application of superheaters small locomotives may be made to haul trains equal to those now hauled by saturated steam locomotives of greater weight, and this means that where traffic has outgrown the locomotive and the right of way conditions not permitting of heavier units of power being introduced, trains may be increased in weight by the adoption of superheaters, and thus the time may be deferred when it will be necessary to strengthen up the bridges and general track structure to meet demands for greater economy in the movement of trains.

TABLE I.
SUPERHEATER DIMENSIONS AND HEATING SURFACE.

PENNSYLVANIA RAILROAD COMPANY.
Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877.)

Superheater.	Length of superheater in flue.	Heating surface, square feet.			Ratio of length of tube to its internal diameter.	Average length of steam passage, inches.	Weights of units, pounds.
		Tubes.	Header.	Return bends.			
Standard.....	ft. in.	946.60	16.92	25.80	848	968	5776
1/4 length.....	19 0	712.96	16.92	25.80	643	734	4348
1/2 length.....	14 0 1/2	474.21	16.92	25.80	434	496	3108
3/4 length.....	9 0 1/4	233.56	16.92	25.80	224	256	1760
Header returns.....	4 0 1/2	15.56	16.92	16.04	21	25	442
Extra length.....	None	1016.48	16.92	25.80	907	1035	6000
Single pass.....	20 5	491.33	16.92	7.87	435	497	2952
Single-pass dummy returns.....	18 7 3/4	491.33	16.92	7.87	435	497	2952
1/4 returns.....	18 7 3/4	617.04	16.92	25.80	559	638	3748
1/2 returns.....	19 0	719.09	16.92	25.80	648	740	4492
3/4 returns.....	19 0	837.83	16.92	25.80	751	857	4888
Spiral plates.....	14 0 1/4	712.96	16.92	25.80	643	734	

TABLE II.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—STANDARD (Altoona, Pa., 10-7-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.87	240-15-F	1.50	56.4	Full	21.6	2115	206.0	3.3	.04	14536	474
3300.88	240-15-F	1.00	56.4	Full	20.7	2100	206.0	3.3	.04	14536	469
3300.89	240-25-F	1.50	56.4	Full	29.8	2347	206.0	6.3	.07	14523	512
3300.90	240-25-F	1.00	56.4	Full	29.7	2350	206.0	5.9	.06	14523	506
3300.91	240-35-F	1.50	56.4	Full	42.9	2480	205.0	10.3	.09	14523	557
3300.92	240-35-F	1.00	56.4	Full	42.2	2480	205.9	10.2	.08	14523	550
3300.93	240-45-F	1.00	56.4	Full	50.7	2627	206.0	14.2	.09	14523	630
3300.94	240-50-F	1.00	56.4	Full	53.3	2690	206.0	15.2	.10	14523	600
3300.95	120-25-F	2.00	28.2	Full	28.1	....	205.1	3.3	.04	14523	481

BOILER PERFORMANCE.										ENGINE PERFORMANCE.	
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour, per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.87	2381	44.3	21803	28044	6.5	11.8	812.9	78.6	5.7	200.3	149.0
3300.88	2337	43.5	21492	27711	6.4	11.9	803.2	79.2	5.4	200.6	151.6
3300.89	3609	67.2	29453	38895	9.0	10.8	1127.4	72.0	11.8	194.2	210.3
3300.90	3681	68.5	29237	38753	9.0	10.5	1123.3	70.4	11.3	194.7	218.5
3300.91	6067	112.9	38481	51684	12.0	8.5	1498.1	56.9	19.8	185.2	253.7
3300.92	5738	106.8	38463	51790	12.0	9.0	1501.2	60.3	19.3	186.6	259.2
3300.93	7417	138.1	48224	64861	15.0	8.7	1880.0	58.4	31.0	175.0	268.8
3300.94	7491	139.5	47877	65071	15.1	8.7	1886.1	58.0	31.3	174.7	288.3
3300.95	2210	41.1	20987	26802	6.2	12.1	776.9	81.1	5.3	199.8	124.9

| ENGINE PERFORMANCE. | | | | | | | | | | LOCOMOTIVE PERFORMANCE. | | | |
| Test number. | Dry steam to engines, pounds per hour. | Indicated horse-power. | Dry fuel per indicated horse-power, pounds. | Dry steam per indicated horse-power, hour, pounds. | Exhaust superheat. | Drawbar pull, pounds. | Dynamometer or drawbar horse-power. | Dry fuel per dynamometer horse-power, pounds. | Dry steam per dynamometer horse-power, hour, pounds. | Machine efficiency of locomotive, per cent. | Thermal efficiency of locomotive, per cent. (based on fuel). | Least back press. |
|
	214	379	380	381		265	383	384	385	398	399	
3300.87	21428	1362.5	1.8	15.7	0	6251	939.9	2.5	22.8	69.0	6.9	2.2
3300.88	21286	1367.3	1.7	15.6	0.3	6233	937.2	2.5	22.7	68.5	7.0	2.2
3300.89	29326	1841.1	2.0	15.9	28.6	9474	1424.5	2.5	20.6	77.4	6.9	4.0
3300.90	29111	1840.9	2.0	15.8	35.4	9514	1430.5	2.6	20.4	77.7	6.8	4.0
3300.91	37942	2254.3	2.7	16.8	67.2	12129	1823.7	3.3	20.8	80.9	5.3	7.9
3300.92	37850	2278.6	2.5	16.6	72.3	12021	1807.5	3.2	20.9	79.3	5.5	7.6
3300.93	46594	2466.6	3.0	18.9	83.6	13784	2072.6	3.6	22.5	84.0	4.9	13.1
3300.94	47458	2520.3	3.0	18.8	107.5	13493	2028.8	3.7	23.4	80.5	4.8	12.7
3300.95	20877	1145.0	1.9	18.2	0.2	12882	968.5	2.3	21.6	84.6	7.7	1.3

TABLE II A.
PENNSYLVANIA RAILROAD COMPANY.
Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal).

SUPERHEATER TESTS—STANDARD (Altoona, Pa., 3-14-1914).

RUNNING CONDITIONS.						BOILER PERFORMANCE.					
Test number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H. P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300. 130	120-25-F	1.75	28.0	Full	26.3	2343	204.8	2.7	0.07	14504	416
3300. 131	240-15-F	1.50	55.9	Full	20.8	2353	206.0	2.9	0.04	14504	429
3300. 132	240-15-F	1.00	55.9	Full	20.9	2377	206.0	2.8	0.04	14504	419
3300. 133	240-25-F	1.50	55.9	Full	28.1	2460	205.0	5.0	0.08	14504	463
3300. 134	240-25-F	1.00	55.9	Full	27.8	2440	204.9	4.9	0.08	14504	451
3300. 135	240-35-F	1.50	55.9	Full	39.7	2493	205.9	8.6	0.12	14504	518
3300. 136	240-35-F	1.00	55.9	Full	39.7	2500	205.9	8.7	0.13	14504	506
3300. 137	240-45-F	0.75	55.9	Full	49.5	2515	205.3	14.0	0.14	14504	568
3300. 138	240-50-F	1.00	55.9	Full	53.8	2545	204.6	16.2	0.10	14504	666

BOILER PERFORMANCE.						ENGINE PERFORMANCE.				
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.		Boiler horse power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lb.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per sq. ft. of fire heating sur.						Per pound of dry fuel.
	338	339	340	344	345	347	350		220	230
3300.130	2295	42.7	20325	26619	6.2	11.6	77.6	5.8	199.0	151.4
3300.131	2282	42.5	21783	28755	6.7	12.6	84.3	5.6	200.4	171.5
3300.132	2262	42.1	21630	28623	6.6	12.7	84.6	5.6	200.4	176.2
3300.133	3257	60.6	28991	38929	9.0	12.0	80.0	8.2	196.8	216.1
3300.134	3361	62.6	28903	38857	9.0	11.6	77.3	7.8	197.1	217.2
3300.135	4983	92.8	37387	51011	11.8	10.2	68.5	15.4	190.5	256.9
3300.136	4897	91.2	37124	50770	11.8	10.4	69.4	15.3	190.6	261.8
3300.137	7301	135.9	46720	64415	14.9	8.8	59.0	24.1	181.2	274.7
3300.138	8985	167.3	50433	69263	16.0	7.7	51.6	31.0	173.6	282.0

ENGINE PERFORMANCE.						LOCOMOTIVE PERFORMANCE.					
Test number.	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power, hour, pounds.	Dry steam per indicated horse-power, hour, pounds.	Exhaust superheat.	Dynamometer or horse-power.	Dry fuel per dynamometer horse-power, hour, pounds.	Dry steam per dynamometer horse-power, hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	385	398	399	
3300.130	20288	1057.1	2.2	19.2	0	12033	897.4	22.6	84.9	6.9	1.4
3300.131	21613	1381.3	1.7	15.7	0	6880	1026.2	21.1	74.3	7.9	3.1
3300.132	21478	1390.7	1.6	15.4	0	6958	1037.9	20.7	74.6	8.1	2.7
3300.133	28821	1771.0	1.8	16.3	4.1	9542	1423.3	2.3	80.4	7.7	4.5
3300.134	28757	1775.1	1.9	16.2	5.4	9507	1418.1	2.4	79.9	7.4	4.3
3300.135	37201	2205.6	2.3	16.9	45.2	13159	1962.8	2.5	89.0	6.9	7.2
3300.136	36928	2209.4	2.2	16.7	52.3	13254	1977.0	2.5	89.5	7.1	7.0
3300.137	46244	2464.0	3.0	18.8	72.7	15543	2318.4	3.2	94.1	5.6	11.2
3300.138	50029	2489.5	3.6	20.1	84.3	15773	2352.7	3.8	94.5	4.6	13.3

TABLE III.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal).

SUPERHEATER TESTS—THREE-QUARTER RETURN (Altoona, Pa., 3-7-1914).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H. P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.116	120-25-F	2.00	28.0	Full	24.4	2296	205.8	2.8	0.04	14809	442
3300.117	240-15-F	1.50	55.9	Full	17.3	2305	206.0	3.3	0.04	14809	466
3300.118	240-15-F	1.00	55.9	Full	17.6	2320	206.0	3.3	0.04	14809	454
3300.119	240-25-F	1.50	55.9	Full	26.8	2497	205.1	5.6	0.08	14809	509
3300.120	240-25-F	1.00	55.9	Full	27.1	2485	205.0	5.5	0.08	14809	498
3300.121	240-35-F	1.50	55.9	Full	38.8	2583	204.0	9.6	0.12	14603	546
3300.122	240-35-F	1.00	55.9	Full	30.1	2295	204.6	9.6	0.11	14603	541
3300.125	240-45-F	1.00	55.9	Full	48.2	2483	201.3	14.8	0.07	14603	538
3300.126	240-50-F	1.00	55.9	Full	51.9	2323	194.9	15.9	0.07	14603	574

BOILER PERFORMANCE.							ENGINE PERFORMANCE.				
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lb.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per sq. ft. of fire heating sur.	Per pound of dry fuel.					
338		339	340			347	349	350		220	230
3300.116	2307	42.9	19409	25549	6.1	11.1	740.6	72.5	5.9	199.8	163.3
3300.117	2325	43.3	21161	27836	6.6	12.0	806.8	78.4	6.3	199.7	164.1
3300.118	2297	42.8	20984	27670	6.6	12.1	802.0	79.0	6.3	199.7	168.5
3300.119	3146	58.6	28597	38275	9.1	12.2	1109.4	79.8	9.7	195.4	206.7
3300.120	3260	60.7	28310	37955	9.0	11.6	1101.1	76.3	9.6	195.4	209.8
3300.121	5605	104.3	37534	50801	12.1	9.1	1472.5	60.2	16.0	188.0	240.9
3300.122	5070	94.4	37360	50728	12.1	10.0	1470.2	66.5	15.3	189.3	244.5
3300.125	7626	142.0	44869	61841	14.7	8.1	1792.5	53.9	21.4	179.9	288.2
3300.126	8709	162.1	47203	64785	15.4	7.4	1877.8	49.4	26.8	168.1	280.2

Test number.	ENGINE PERFORMANCE.				LOCOMOTIVE PERFORMANCE.							
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power hour, pounds.	Dry steam per dynamometer horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300. 116	19279	1044. 0	2. 2	18. 5	7. 6	12271	922. 5	2. 5	20. 9	88. 4	6. 9	1. 1
3300. 117	21007	1329. 1	1. 8	15. 8	0	6761	1016. 0	2. 3	20. 7	76. 5	7. 5	3. 2
3300. 118	20799	1338. 2	1. 7	15. 5	0	6867	1032. 5	2. 2	20. 1	77. 2	7. 7	2. 8
3300. 119	28424	1714. 9	1. 8	16. 6	2. 9	10329	1540. 7	2. 0	18. 5	80. 8	8. 4	4. 3
3300. 120	28170	1723. 7	1. 9	16. 3	2. 8	10331	1541. 0	2. 1	18. 3	89. 4	8. 1	4. 1
3300. 121	37289	2183. 7	2. 0	17. 1	28. 9	12903	1924. 9	2. 9	19. 4	88. 2	6. 0	8. 2
3300. 122	37126	2196. 4	2. 3	16. 9	34. 5	12911	1925. 8	2. 6	19. 3	87. 7	6. 6	8. 1
3300. 125	44636	2411. 1	3. 2	18. 5	85. 5	14428	2152. 1	3. 5	20. 7	80. 3	4. 9	11. 8
3300. 126	47000	2436. 5	3. 6	19. 3	90. 2	15098	2252. 0	3. 9	20. 9	92. 4	4. 5	13. 9

TABLE IV.
AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.
Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)
SUPERHEATER TESTS—ONE-HALF LENGTH (Altoona, Pa., 8-26-1913).

RUNNING CONDITIONS.						BOILER PERFORMANCE.					
Test number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H. P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199	203	268 to 271		217	222	225	248	238
3300.23	240-15-F	1.50	56.59	Full	20.3	2260	204.5	3.4	.08	14500	496
3300.24	240-15-F	1.00	56.59	Full	20.8	2245	204.6	3.5	.09	14500	494
3300.25	240-25-F	1.50	56.59	Full	28.3	2273	205.0	6.8	.13	14500	552
3300.26	240-25-F	1.00	56.59	Full	28.7	2270	205.0	6.6	.13	14500	548
3300.27	240-35-F	1.50	56.59	Full	41.9	2360	204.5	12.1	.18	14500	593
3300.28	240-35-F	1.00	56.59	Full	43.2	2360	204.1	12.2	.17	14500	592
3300.29	240-45-F	1.00	56.59	Full	49.3	2400	205.0	17.6	.11	14500	622
3300.30	240-50-F	0.50	56.59	Full	53.2	2580	187.3	17.2	.10	14500	594

Test number.	BOILER PERFORMANCE.						ENGINE PERFORMANCE.			
	Dry fuel fired per hour, pounds.	Dry fuel per hour, sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.		Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.						Per pound of dry fuel.
338	339	340	344	345	347	349	350		220	230
3300.23	2812	52.4	31302	8.2	11.1	907.3	74.5	7.3	197.2	82.2
3300.24	2780	51.8	31194	8.1	11.2	904.2	75.1	6.9	197.7	84.4
3300.25	4412	82.1	43973	11.5	10.0	1274.6	66.7	14.5	190.5	115.3
3300.26	4427	82.4	34785	11.5	9.9	1274.1	66.5	14.3	190.7	117.8
3300.27	6188	115.2	44801	14.9	9.2	1655.4	61.8	21.0	183.5	146.9
3300.28	6332	117.9	44600	14.8	9.0	1650.9	60.2	20.5	183.6	150.5
3300.29	9031	168.1	56957	18.2	7.7	2023.8	51.7	27.0	178.0	146.9
3300.30	10020	186.5	69819	17.3	6.6	1919.8	44.2	26.8	160.5	149.4

LOCOMOTIVE PERFORMANCE.

Test number.	ENGINE PERFORMANCE.				Exhaust super-heat.
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	
	214	379	380	381	
3300.23	24877	1362.3	2.1	18.3	0
3300.24	24702	1365.2	2.0	18.1	0
3300.25	34723	1773.4	2.5	19.6	6.6
3300.26	34635	1772.0	2.5	19.6	6.4
3300.27	44514	2125.5	2.9	20.9	3.0
3300.28	44408	2178.9	2.0	20.4	2.8
3300.29	53883	2402.8	3.8	22.4	8.6
3300.30	51708	2195.9	4.6	23.6	6.9

Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power, hour, pounds.	Dry steam per dynamometer horse-power, hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
265	383	384	385	398	399	
6478	977.5	2.9	25.5	71.8	6.1	5.7
6339	956.6	2.9	25.8	70.1	6.0	5.6
9019	1451.6	3.0	23.9	81.9	5.8	8.3
9671	1459.4	3.0	23.7	82.4	5.8	7.5
12642	1907.8	3.2	23.3	89.8	5.4	11.6
12637	1907.0	3.3	23.3	87.5	5.3	11.6
13857	2091.1	4.3	25.8	87.0	4.1	15.8
13155	1985.2	5.1	26.1	90.4	3.5	15.3

TABLE V.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—ONE-QUARTER LENGTH (Altoona, Pa., 9-8-1913).

RUNNING CONDITIONS.						BOILER PERFORMANCE.					
Test number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199	203	268 to 271		217	222	225	248	238
3300.39	240-15-F	1.50	56.59	Full	19.6	2220	205.0	4.3	.08	14577	429
3300.40	240-15-F	1.00	56.59	Full	19.4	2200	205.0	4.3	.08	14577	421
3300.41	240-25-F	1.50	56.59	Full	31.0	2290	205.0	8.5	.15	14577	478
3300.42	240-25-F	1.00	56.59	Full	31.1	2295	205.0	8.5	.16	14577	471
3300.43	240-35-F	1.50	56.59	Full	40.9	2343	202.7	14.0	.13	14553	515
3300.44	240-35-F	1.00	56.59	Full	40.6	2360	204.3	14.6	.13	14553	505

BOILER PERFORMANCE.							ENGINE PERFORMANCE.				
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.39	3307	61.6	27013	31662	8.8	9.6	917.8	63.7	7.4	197.6	51.5
3300.40	3189	59.4	27027	33243	9.2	10.4	993.6	69.4	7.3	197.7	53.3
3300.41	4027	91.7	38791	48163	13.4	9.8	1390.0	65.1	11.5	193.5	76.1
3300.42	4922	91.6	38353	47646	13.2	9.7	1381.1	64.4	11.7	193.3	77.6
3300.43	8687	161.7	49953	62335	17.3	7.2	1806.8	47.9	17.6	185.1	88.9
3300.44	8692	161.8	50553	63225	17.3	7.3	1803.6	48.5	17.6	186.7	92.3

ENGINE PERFORMANCE.						LOCOMOTIVE PERFORMANCE.						
Test number.	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power hour, pounds.	Dry steam per dynamometer horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300. 39	26688	1344. 2	2. 5	19. 9	0	6090	919. 0	3. 6	29. 0	68. 4	4. 9	4. 6
3300. 40	26644	1352. 9	2. 4	19. 7	0	5931	895. 0	3. 6	29. 8	66. 2	4. 9	4. 4
3300. 41	38516	1765. 8	2. 8	21. 8	2. 7	10049	1516. 5	3. 3	25. 4	85. 9	5. 4	8. 4
3300. 42	38126	1756. 2	2. 8	21. 7	3. 0	10012	1510. 9	3. 3	25. 2	86. 0	5. 4	8. 3
3300. 43	49536	2102. 9	4. 1	23. 6	3. 9	12365	1866. 0	4. 7	26. 6	88. 7	3. 8	14. 7
3300. 44	50088	2118. 4	4. 1	23. 6	5. 4	12785	1929. 3	4. 5	26. 0	91. 9	3. 9	14. 2

TABLE VI.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—HEADER RETURNS (Altoona, Pa., 9-20-1913).

RUNNING CONDITIONS.							BOILER PERFORMANCE.				
Test number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.64	240-15-F	1.50	56.6	Full	22.1	2233	204.9	4.9	.08	14163	620
3300.65	240-15-F	1.00	56.6	Full	22.4	2230	205.1	5.0	.08	14163	626
3300.66	240-25-F	0.50	56.6	Full	31.2	2380	177.8	7.0	.10	14163	710
3300.67	240-20-F	0.50	56.6	Full	26.2	2310	190.5	5.6	.09	14163	698
3300.68	120-25-F	2.00	28.3	Full	30.8	2170	205.0	4.1	.07	14163	622

BOILER PERFORMANCE.										ENGINE PERFORMANCE.	
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per sq. ft. of fire heating sur.	Per pound of dry fuel.					
338	339	340	344	345	347	349	350		220	230	
3300.64	4509	83.9	30960	37522	11.1	8.3	1087.6	57.0	5.6	199.3	16.6
3300.65	4268	79.5	30820	37345	11.1	8.8	1082.5	60.0	5.5	199.6	15.9
3300.66	5048	94.0	37656	45718	13.6	9.1	1325.2	62.1	9.0	168.8	24.6
3300.67	4152	77.3	33594	40724	12.1	9.8	1180.4	67.2	7.5	183.0	18.9
3300.68	3660	68.1	28400	34445	10.2	9.4	998.4	64.5	5.2	199.8	18.5

ENGINE PERFORMANCE.										LOCOMOTIVE PERFORMANCE.			
Test number.	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power, hour, pounds.	Dry steam per indicated horse-power, hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power, hour, pounds.	Dry steam per dynamometer horse-power, hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.	
214	379	380	381		265	383	384	385	398	399			
3300.64	30703	1423.1	3.2	21.6	0	5559	838.9	5.4	36.6	50.0	3.3	7.3	
3300.65	30651	1425.2	3.0	21.5	0	5005	845.8	5.1	36.2	59.4	3.6	7.0	
3300.66	37493	1547.0	3.3	24.2	0	7249	1093.9	4.6	34.3	70.7	3.9	9.4	
3300.67	33449	1476.7	2.8	22.7	1.6	6096	919.9	4.5	36.4	62.3	4.0	7.7	
3300.68	28278	1147.9	3.2	24.6	1.8	11725	884.7	4.1	32.0	77.1	4.3	4.4	

TABLE VII.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—EXTRA LENGTH (Altoona, Pa., 9-17-1913).

RUNNING CONDITIONS.						BOILER PERFORMANCE.					
Test number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.55	240-15-F	1.50	56.6	Full	21.5	1835	206.0	3.0	.06	14552	411
3300.56	240-15-F	1.00	56.6	Full	21.7	1827	206.0	2.9	.06	14552	413
3300.57	240-25-F	1.50	56.6	Full	30.8	2180	206.0	5.9	.10	14552	545
3300.58	240-25-F	1.00	56.6	Full	30.7	2200	206.0	5.9	.10	14552	546
3300.59	240-35-F	1.50	56.6	Full	42.6	2460	205.6	9.8	.12	14163	592
3300.60	240-35-F	1.00	56.6	Full	42.4	2460	206.0	9.5	.12	14163	595
3300.61	240-45-F	1.00	56.6	Full	51.8	2500	205.4	13.6	.15	14163	603
3300.62	240-50-F	1.00	56.6	Full	52.4	2487	205.0	15.4	.10	14163	604
3300.63	120-25-F	2.00	28.3	Full	29.9	1973	205.8	3.0	.07	14163	449

TABLE VIII.
AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.
Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)
SUPERHEATER TESTS—SINGLE PASS (Altoona, Pa., 9-27-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199.	203	268 to 271		217	222	225	248	238
3300.69	240-15-F	1.50	56.6	Full	22.5	2023	205.5	3.1	.05	14163	572
3300.70	240-15-F	1.00	56.6	Full	22.5	2035	205.3	3.1	.04	14163	563
3300.71	240-25-F	1.50	56.6	Full	30.6	2336	204.9	6.1	.07	14163	634
3300.72	240-25-F	1.00	56.6	Full	30.8	2347	204.9	6.0	.08	14163	629
3300.73	240-35-F	1.50	56.6	Full	41.1	2403	201.7	10.2	.08	14536	651
3300.74	240-35-F	1.00	56.6	Full	41.4	2405	201.3	10.3	.09	14536	646
3300.75	240-45-F	0.25	56.6	Full	51.9	...	182.3	12.0	.08	14536	647
3300.76	120-25-F	2.00	28.3	Full	31.5	2106	205.1	3.0	.05	14536	551

Test number.	BOILER PERFORMANCE.						ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation and at 212° F., pounds.		Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.
				Per hour.	Per sq. ft. of fire heating sur.			
	338	339	340	344	345	347	350	
3300.69	2542	47.3	24185	30831	8.0	12.1	83.1	5.4
3300.70	2579	48.0	24063	30726	8.0	11.9	81.6	5.0
3300.71	4304	81.8	33051	43804	11.4	10.0	68.5	8.7
3300.72	4350	81.0	33851	43877	11.4	10.1	69.1	8.5
3300.73	7245	134.9	42872	55979	14.6	7.7	51.6	14.3
3300.74	6578	122.5	42336	55473	14.5	8.4	56.3	14.2
3300.75	8816	164.1	47920	62577	16.3	7.1	47.4	20.0
3300.76	2597	48.3	22610	28855	7.5	11.1	74.2	4.9

Test number.	ENGINE PERFORMANCE.						LOCOMOTIVE PERFORMANCE.				
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power hour, pounds.	Dry steam per dynamometer horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).
	214	379	380	381		265	383	384	385	398	399
3300.69	23884	1382.7	1.8	17.3	0	5197	784.3	3.2	30.5	56.7	5.6
3300.70	23882	1379.1	1.9	17.3	0	5136	775.0	3.3	30.8	56.2	5.4
3300.71	33804	1879.9	2.3	18.0	0	8849	1350.5	3.3	25.0	71.9	5.5
3300.72	33705	1879.9	2.3	17.9	2.3	8937	1348.7	3.2	25.0	71.8	5.6
3300.73	42687	2237.9	3.2	19.1	3.3	11071	1670.7	4.3	25.6	74.7	4.0
3300.74	42153	2243.0	2.9	18.8	2.7	11101	1675.3	3.9	25.2	74.7	4.5
3300.75	47686	2273.6	3.9	21.0	23.2	11851	1788.5	4.9	26.7	78.7	3.6
3300.76	22453	1158.7	2.2	19.4	0	11317	853.9	3.0	26.3	73.7	5.8

TABLE IX.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—SINGLE PASS, DUMMY RETURNS (Altoona, Pa., 10-1-1913).

RUNNING CONDITIONS.						BOILER PERFORMANCE.					
Test number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199	203	268 to 271		217	222	225	248	238
3300.77	120-25-F	1.50	28.2	Full	29.1	2210	205.6	3.8	.06	14536	469
3300.78	240-15-F	1.50	56.4	Full	21.3	1960	205.7	3.4	.06	14536	488
3300.79	240-15-F	1.00	56.4	Full	21.2	1960	206.0	3.4	.05	14536	487
3300.80	240-25-F	1.50	56.4	Full	28.4	2331	205.9	7.1	.08	14536	526
3300.81	240-25-F	1.00	56.4	Full	28.5	2335	205.9	6.9	.08	14536	521
3300.82	240-35-F	1.50	56.4	Full	41.6	2410	206.0	12.3	.13	14536	592
3300.83	240-35-F	1.00	56.4	Full	41.4	2415	206.0	12.2	.13	14536	595
3300.84	240-45-F	1.00	56.4	Full	50.6	2450	196.6	14.8	.08	14536	581
3300.85	240-50-F	0.25	56.4	Full	51.5	...	190.3	15.2	.08	14536	600
3300.86	120-25-F	2.00	28.2	Full	29.2	2128	205.8	3.2	.05	14536	449

BOILER PERFORMANCE.										ENGINE PERFORMANCE.	
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.)	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.77	2576	48.0	24192	30264	7.9	11.8	877.2	78.5	6.1	199.5	90.8
3300.78	2871	53.4	24326	30683	8.0	10.7	889.4	71.4	5.7	200.0	95.7
3300.79	2596	48.3	24192	30553	8.0	11.8	885.6	78.6	5.6	200.4	97.1
3300.80	3710	69.1	33940	43378	11.3	11.7	1257.3	77.0	10.6	195.3	127.8
3300.81	3747	69.8	33789	43310	11.3	11.6	1255.4	77.2	10.5	195.4	132.8
3300.82	6271	116.7	44166	57090	14.9	9.1	1654.8	60.8	14.5	191.5	157.3
3300.83	6095	113.5	43857	56947	14.8	9.3	1650.6	62.4	14.6	192.0	166.7
3300.84	9044	168.4	52299	67717	17.6	7.5	1962.8	50.0	20.7	175.9	169.0
3300.85	9180	170.9	52032	67231	17.5	7.3	1948.7	48.9	22.0	168.3	165.8
3300.86	2312	43.0	22720	28766	7.5	12.4	833.8	83.1	5.1	200.7	104.7

| ENGINE PERFORMANCE. | | | | | | | | | | LOCOMOTIVE PERFORMANCE. | | |
| Test number. | Dry steam to engines, pounds per hour. | Indicated horse-power. | Dry fuel per indicated horse-power, hour, pounds. | Dry steam per indicated horse-power, hour, pounds. | Exhaust. super-heat. | Drawbar pull, pounds. | Dynamometer or drawbar horse-power. | Dry fuel per dynamometer horse-power, hour, pounds. | Dry steam per dynamometer horse-power, hour, pounds. | Machine efficiency of locomotive, per cent. | Thermal efficiency of locomotive, per cent. (based on fuel). | Least back press. |
|
	214	379	380	381		265	383	384	385	398	399	
3300.77	24058	1146.4	2.3	21.0	0	12725	956.7	2.7	25.2	83.5	6.5	2.6
3300.78	24044	1308.4	2.2	18.4	0	6023	905.6	3.2	26.6	69.2	5.5	3.0
3300.79	23918	1313.6	2.0	18.2	0	5938	892.8	2.9	26.8	68.0	6.0	3.0
3300.80	33519	1732.9	2.1	19.3	0.7	9102	1368.2	2.7	24.5	79.0	6.5	6.1
3300.81	33546	1773.8	2.1	18.9	0.3	9165	1578.0	2.7	24.3	77.7	6.4	6.3
3300.82	43911	2212.4	2.8	19.9	2.3	12076	1815.7	3.5	24.2	82.1	5.1	11.0
3300.83	43637	2229.6	2.7	19.6	2.9	12098	1819.1	3.4	24.0	81.6	5.2	10.7
3300.84	51924	2474.7	3.7	21.0	7.8	13361	2009.0	4.5	25.9	81.2	3.9	14.1
3300.85	51868	2369.7	3.9	21.0	14.3	13047	1961.7	4.7	26.4	82.8	3.7	14.9
3300.86	22328	1126.1	2.1	19.8	0	12407	932.8	2.5	23.9	82.8	7.1	2.0

TABLE X.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—ONE-QUARTER RETURNS (Altoona, Pa., 10-15-1913).

RUNNING CONDITIONS.						BOILER PERFORMANCE.					
Test. number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off, per cent., H.P. cylinders.	Fire- box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke box temp.
	R. P. M. cut- off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.99	240-15-F	1.50	56.4	Full	20.7	2257	205.9	2.9	.04	14523	474
3300.100	240-15-F	1.00	56.4	Full	20.5	2235	205.9	2.9	.04	14523	470
3300.101	240-25-F	1.50	56.4	Full	30.1	2395	205.4	5.9	.08	14487	539
3300.102	240-25-F	1.00	56.4	Full	29.6	2410	205.6	5.7	.08	14487	540
3300.103	240-35-F	1.00	56.4	Full	41.1	2365	206.0	10.2	.08	14487	529
3300.104	240-35-F	0.50	56.4	Full	41.2	2350	206.0	10.0	.08	14487	565
3300.105	240-45-F	1.00	56.4	Full	52.6	2515	203.4	14.2	.07	14487	605
3300.106	120-25-F	2.00	28.2	Full	30.1	2162	206.0	3.1	.05	14487	474

BOILER PERFORMANCE.										ENGINE PERFORMANCE.	
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per sq. ft. of fire heating sur.	Per pound of dry fuel.					
3300.99	338	339	340	344	345	347	349	350		220	230
3300.100	2362	44.0	22123	28277	7.1	12.0	819.6	80.0	4.4	201.5	135.6
3300.101	2412	44.9	22008	28211	7.1	11.7	817.7	78.2	4.3	201.6	138.3
3300.102	3924	73.0	31342	40635	10.2	10.4	1177.8	69.4	11.0	194.4	170.2
3300.103	3690	68.7	31259	40752	10.2	11.0	1181.2	74.0	10.9	194.7	177.8
3300.104	5771	107.4	40419	53852	13.5	9.3	1560.9	62.5	15.9	190.1	230.3
3300.105	5884	109.5	39330	52527	13.2	8.9	1522.5	59.8	15.2	190.8	235.5
3300.106	9635	179.4	48908	65323	16.4	6.8	1893.4	45.5	23.7	179.7	239.6
	2542	47.3	21527	27592	6.9	10.9	799.8	72.7	4.5	201.5	131.5

LOCOMOTIVE PERFORMANCE.												
Test number.	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power hour, pounds.	Dry steam per dynamometer horse-power hour, pounds.	Machine efficiency of locomotive, per cent. (based on fuel).	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
3300.99	214	379	380	381		265	383	384	385	398	399	
3300.100	21837	1366.0	1.7	16.0	0	6397	961.9	2.5	22.7	70.4	7.1	0.4
3300.101	21729	1368.2	1.8	15.9	0	6240	938.2	2.6	23.2	68.6	6.8	0.9
3300.102	31088	1787.0	2.2	17.4	3.7	9904	1489.2	2.6	20.9	83.3	6.7	3.1
3300.103	30968	1789.6	2.1	17.3	3.7	9791	1472.2	2.5	21.0	82.3	7.0	2.4
3300.104	39452	2276.9	2.5	17.3	51.3	12735	1914.8	3.0	20.6	84.1	5.8	6.1
3300.105	30079	2277.5	2.6	17.2	55.8	12735	1914.8	3.1	20.4	84.1	5.7	5.5
3300.106	48168	2489.3	3.9	19.4	72.7	13410	2016.3	4.8	23.9	81.0	3.7	10.6
	21429	1141.7	2.2	18.8	2.4	12988	976.4	2.6	22.0	85.5	6.8	1.5

TABLE XI.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—ONE-HALF RETURNS (Altoona, Pa., 9-12-1913).

Test. number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire- box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke- box temp.
	R. P. M. cut- off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.46	240-15-F	1.50	56.6	Full	20.7	2023	206.0	3.4	.06	14553	419
3300.47	240-15-F	1.00	56.6	Full	23.2	2005	206.0	3.4	.06	14553	415
3300.48	240-25-F	1.50	56.6	Full	28.8	2298	205.5	6.3	.09	14553	448
3300.49	240-25-F	1.00	56.6	Full	29.7	2298	205.7	6.2	.09	14553	433
3300.50	240-35-F	1.50	56.6	Full	42.3	2376	205.6	11.2	.16	14553	512
3300.51	240-35-F	1.00	56.6	Full	42.6	2382	205.6	11.2	.17	14553	504
3300.52	240-45-F	1.00	56.6	Full	50.4	2465	205.3	15.9	.14	14553	531
3300.53	240-50-F	1.00	56.6	Full	54.0	2585	205.0	16.2	.13	14553	508
3300.54	120-20-F	2.00	28.3	Full	28.9	1798	205.3	3.5	.07	14553	...

Test number.	BOILER PERFORMANCE.						ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.		Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.
				Per hour.	Per sq. ft. of fire heating sur.			
	338	339	340	344	345	347	350	220
3300.46	2773	51.6	22787	29134	7.1	10.5	70.1	196.6
3300.47	2687	50.0	22766	29207	7.2	10.9	72.5	196.9
3300.48	3358	71.8	31130	40629	9.9	10.5	70.2	193.5
3300.49	3822	81.2	31123	41044	10.1	10.7	71.6	194.0
3300.50	5298	98.6	39322	52794	12.9	10.0	65.3	187.7
3300.51	5278	98.3	39003	52481	12.9	9.9	66.3	187.6
3300.52	7494	139.5	47612	64497	15.8	8.6	57.4	180.1
3300.53	7480	139.2	49905	66724	16.3	8.9	59.5	178.3
3300.54	2457	45.7	29938	26921	6.6	11.0	73.1	199.8
								230
								146.7
								152.9
								214.4
								221.6
								272.4
								278.8
								297.5
								263.6
								159.4

Test number.	ENGINE PERFORMANCE.						LOCOMOTIVE PERFORMANCE.			
	Dry steam engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power hour, pounds.	Dry steam per dynamometer horse-power hour, pounds.	Machine efficiency of locomotive, per cent.
	214	379	380	381		265	383	384	385	398
3300.46	22614	1437.2	1.9	15.7	0	6854	1034.3	2.7	21.9	72.0
3300.47	22556	1449.9	1.9	15.6	0	6874	1037.3	2.6	21.8	71.6
3300.48	30927	1926.7	2.0	16.1	13.2	11067	1670.1	2.3	18.5	86.7
3300.49	30887	1926.1	2.0	16.0	17.4	11180	1687.1	2.3	18.3	87.6
3300.50	30976	2342.3	2.3	16.7	62.2	13289	2005.4	2.6	19.5	85.6
3300.51	38835	2355.3	2.2	16.5	69.6	13219	1994.9	2.7	19.5	84.7
3300.52	47093	2592.3	2.9	18.2	98.5	14713	2220.9	3.4	21.2	85.7
3300.53	49379	2597.6	2.9	19.0	81.4	13828	2086.8	3.6	23.7	80.3
3300.54	20789	1162.6	2.1	17.9	0	11793	889.8	2.8	23.4	76.5
										399
										6.5
										6.8
										7.6
										7.7
										6.6
										7.9
										12.9
										15.1
										6.3
										2.4
										2.3
										4.8
										4.5
										8.0
										6.6
										5.2
										4.9
										6.3

LOCOMOTIVE PERFORMANCE.

ENGINE PERFORMANCE.

TABLE XII.
AVERAGE RESULTS OF LOCOMOTIVE TESTS.
PENNSYLVANIA RAILROAD COMPANY.
Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)
SUPERHEATER TESTS—THREE-QUARTERS RETURNS (Altoona, Pa., 10-22-1913).

RUNNING CONDITIONS.						BOILER PERFORMANCE.					
Test number.	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300. 107	120-25-F	2.00	28.2	Full	28.6	2014	206.0	3.1	.05	14487	494
3300. 108	240-15-F	1.50	56.4	Full	21.0	2117	206.0	2.7	.06	14487	510
3300. 109	240-15-F	1.00	56.4	Full	20.6	2070	206.0	2.7	.05	14487	509
3300. 110	240-25-F	1.50	56.4	Full	31.1	2327	205.8	5.5	.07	14487	562
3300. 111	240-25-F	1.00	56.4	Full	30.9	2335	205.7	5.5	.07	14487	561
3300. 112	240-35-F	1.50	56.4	Full	42.2	2430	206.0	9.8	.10	14487	594
3300. 113	240-35-F	1.00	56.4	Full	42.0	2440	206.0	9.5	.10	14487	582
3300. 114	240-45-F	1.00	56.4	Full	52.7	2490	205.3	13.8	.08	14487	621
3300. 115	240-50-F	1.00	56.4	Full	53.7	2590	204.6	13.8	.06	14121	614

BOILER PERFORMANCE.										ENGINE PERFORMANCE.	
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horsepower (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per sq. ft. of fire heating sur.	Per pound of dry fuel.					
338		339	340	344	345	347	349	350		220	230
3300. 107	2221	41.3	21353	27395	6.5	12.3	794.1	82.6	7.0	199.0	134.2
3300. 108	2600	48.4	22201	28424	6.8	10.9	823.9	73.2	6.9	199.1	129.6
3300. 109	2374	44.2	22005	28260	6.7	11.9	819.1	79.7	6.6	199.4	134.1
3300. 110	3719	69.2	30442	39841	9.5	10.7	1154.8	71.7	14.6	191.2	179.3
3300. 111	3616	67.3	30424	39800	9.5	11.0	1156.2	73.9	14.3	191.4	186.3
3300. 112	5160	96.1	39674	52800	12.6	10.2	1530.4	68.5	25.0	181.0	226.6
3300. 113	5215	97.1	39192	52299	12.4	10.0	1515.9	67.2	24.0	182.0	232.1
3300. 114	7653	142.5	47490	63571	15.1	8.3	1842.4	55.7	33.6	171.7	245.2
3300. 115	10793	200.9	47931	64438	15.3	6.0	1867.8	41.0	29.5	175.1	253.0

LOCOMOTIVE PERFORMANCE.											
Test number.	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Dynamometer or drawbar power.			Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, (based on fuel).	Least back press.
Drawbar pull, pounds.	Dry fuel per dynamometer horse-power.	Dry steam per dynamometer horse-power hour, pounds.									
214		379	380	381		265	383	384	385	398	399
3300. 107	21261	1130.5	2.0	18.8	2.4	12958	974.2	2.3	21.8	86.2	7.7
3300. 108	21969	1357.1	1.9	16.2	5.5	6690	1005.9	2.6	21.8	74.1	6.8
3300. 109	21783	1360.3	1.8	16.0	5.4	6402	962.6	2.5	22.6	70.8	7.1
3300. 110	30311	1823.0	2.0	16.6	10.7	9999	1503.4	2.5	20.2	82.5	7.1
3300. 111	30293	1825.9	2.0	16.6	11.8	9806	1474.4	2.5	20.6	80.8	7.2
3300. 112	39166	2264.9	2.3	17.3	54.4	13259	1993.6	2.6	19.7	88.0	6.8
3300. 113	38721	2270.0	2.3	17.1	59.2	13009	1956.0	2.7	19.8	86.2	6.6
3300. 114	46777	2467.1	3.1	19.0	79.2	13677	2056.5	3.7	22.8	83.4	4.7
3300. 115	47636	2463.7	4.4	19.3	89.5	13934	2095.1	5.2	22.7	85.0	3.5

TABLE XIII.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.

Northern Central Railway Company.

West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)
 SUPERHEATER TESTS—SPIRAL PLATES (Altoona, Pa., 9-2-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.31	240-15-F	1.50	56.59	Full	19.2	2277	205.9	3.6	.07	14577	448
3300.32	240-15-F	1.00	56.59	Full	19.6	2285	205.9	3.6	.07	14577	447
3300.33	240-25-F	1.25	56.59	Full	28.6	2323	204.8	6.5	.10	14577	513
3300.34	240-25-F	0.75	56.59	Full	28.8	2330	204.8	6.5	.10	14577	507
3300.35	240-35-F	1.50	56.59	Full	41.1	2400	206.0	10.6	.12	14577	544
3300.36	240-35-F	1.00	56.59	Full	41.3	2495	206.0	10.4	.12	14577	543
3300.37	240-45-F	1.00	56.59	Full	50.2	2470	204.9	15.2	.14	14577	540
3300.38	240-50-F	1.00	56.59	Full	52.3	2490	205.6	14.9	.14	14577	543

BOILER PERFORMANCE.										ENGINE PERFORMANCE.	
Test number.	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horsepower (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per sq. ft. of fire heating sur.	Per pound of dry fuel.					
338	339	340	344	345	347	349	350	220	230		
3300.31	2765	51.5	23627	20665	7.3	10.7	859.9	71.4	11.4	194.5	104.1
3300.32	2843	52.9	23745	29857	7.3	10.5	865.4	69.9	11.2	194.7	106.5
3300.33	3838	- 71.5	31949	40893	10.0	10.7	1185.3	70.9	20.4	184.4	151.7
3300.34	3772	70.2	31584	40499	9.9	10.7	1173.9	71.5	20.2	184.6	155.1
3300.35	5366	99.9	40939	52888	13.0	9.9	1532.8	65.6	32.8	173.2	177.1
3300.36	5340	99.4	41005	53102	13.0	9.9	1539.2	66.0	32.6	173.4	182.0
3300.37	6891	128.3	48058	62311	15.3	9.0	1806.1	60.2	41.5	163.4	191.4
3300.38	7110	132.4	48384	62945	15.4	8.9	1824.5	58.9	44.5	161.1	197.3

ENGINE PERFORMANCE.										LOCOMOTIVE PERFORMANCE.			
Test number.	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power, hour, pounds.	Dry steam per indicated horse-power, hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamometer horse-power, hour, pounds.	Dry steam per dynamometer horse-power, hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.	
214	379	380	381			265	383	384	385	398	399		
3300.31	23499	1376.9	2.0	17.1	1.7	6340	956.7	2.9	24.6	69.5	6.0	4.1	
3300.32	23604	1378.1	2.1	17.1	1.8	6192	934.4	3.0	25.3	67.8	5.7	4.1	
3300.33	31709	1775.6	2.2	17.9	1.8	9513	1435.6	2.7	22.1	80.9	6.5	6.3	
3300.34	31360	1778.0	2.1	17.6	1.4	9437	1424.1	2.7	22.0	80.1	6.6	6.0	
3300.35	40762	2088.2	2.6	19.5	2.6	12080	1822.9	2.9	22.4	87.3	5.9	8.3	
3300.36	40829	2098.5	2.5	19.5	3.3	12112	1827.8	2.9	22.3	79.5	6.0	7.9	
3300.37	47396	2200.6	3.1	21.5	22.4	12967	1956.8	3.5	24.2	88.9	5.0	11.9	
3300.38	48014	2208.3	3.2	21.7	31.1	13607	2053.4	3.5	23.4	93.0	5.1	11.9	

(To be continued.)

Rail Steels for Electric Railways. W. WILLCOX. (*Times, Eng. Suppl.*, Feb. 25, 1914.)—This gives the results of some tests made to determine the most suitable rail to withstand the heavy wear of electric railway rolling stock. For the last seven years high-silicon steel has been used and has proved more durable and considerably less liable to rust than ordinary steel. It is made from basic open-hearth, basic Bessemer, or acid Bessemer steels by the Sandberg process, in which during the manufacture the whole of the silicon is extracted and a known quantity added. The rails are 45 feet long and weigh 86 lbs. per yard. The results as regards life were: High-silicon basic open-hearth, over 23 months; high-silicon acid Bessemer, first lot of rails on the down road, 11 months, second lot of rails just over 15 months, and on the up road, just over 15 months; basic open-hearth titanium, $9\frac{1}{3}$ months; and ordinary basic open-hearth $9\frac{1}{3}$ months on the down road, and barely 11 months average on the up road. Silicon steel is especially suitable in tunnels, on account of its comparative freedom from rusting as compared with ordinary steel; moreover the price is not more than 10 per cent. per ton in excess of the price of ordinary steel, whereas nickel steel, chrome steel, etc., cost much more. A test was made of rolled manganese-steel rails, containing C, 1.20; SiO_2 , 0.30; S, 0.03; P, 0.06; and Mn, 12.00 per cent. Two pairs of 95-lb. rolled manganese rails of British standard section were placed near Moorgate Street on a 15 chain curve. After being there nine months, they were put on the curve between Farringdon Street and Aldersgate Street, on the down road just outside the tunnel. The original weights when put in the road near Moorgate Street were No. 1 high rail, 1425 lbs.; No. 1 low rail, 1427 lbs.; No. 2 high rail, 1428 lbs.; and No. 2 low rail 1400 lbs. When put in the curve at Farringdon Street on January 6, 1912, No. 1 high rail had lost 22 lbs. in weight, No. 1 low rail 17 lbs., No. 2 high rail 14 lbs. and No. 2 low rail 17 lbs. This gives an average loss of 1.56 lbs. per yard per annum. Weighed again on Oct. 11, 1913, the weights were No. 1 high rail 1333 lbs.; No. 1 low rail, 1393; No. 2 high rail, 1375 lbs., and No. 2 low rail 1365 lbs. The total loss in weight: No. 1 high rail, 92 lbs.; No. 1 low rail, 34 lbs.; No. 2 high rail, 53 lbs., and No. 2 low rail, 35 lbs., equal to an average of 1.43 lbs. per yard per annum. After a period of two years and six months these rails, although wearing away, are wearing evenly, and show no signs of battering, as even the hardest of the other rails tested did.

RESISTIVITY OF PURE SILVER; SOLID AND MOLTEN.*

BY

EDWIN F. NORTHRUP, Ph.D.,

Palmer Physical Laboratory, Princeton University.

Member of the Institute.

THE silver used in the measurements here recorded was very pure. It was given to the writer by Prof. G. A. Hulett from the supply which he is using in connection with his study of the silver voltameter. The writer takes this opportunity of expressing his very great indebtedness to Professor Hulett not only for supplying the silver for the measurements recorded here, but also for numerous courtesies and encouragements rendered the writer in connection with his general research.

The resistivity of the silver in the form of a soft drawn wire was determined between 20° C. and 60° C., using an oil-bath, mercury thermometer, and Kelvin double bridge. The same silver was then used in a container and measured as the temperature was slowly decreased and increased between 1340° C. and 20° C.

The manner of making the measurement and the apparatus used were the same as have already been described by the writer in this JOURNAL, in the articles, "Resistivity of Copper in Temperature Range 20° C. to 1450° C." (January, 1914), and "Resistivity of Pure Gold in Temperature Range 20° C. to 1500° C." (March, 1914).

While it has been the writer's custom to repeat the determination using a different container in each case and thereby check the precision of his results, this was not done in the case of silver because of press of other investigations and because his increased familiarity with the method employed makes it entirely unlikely that any gross error has intruded.

The results obtained are fully set forth in Curves I, II, and III, and in the table at the end of the article.

Curve I is a plot of the resistivity of silver in the form of a soft drawn wire in the range 20° to 60° C.

* Communicated by the Author.

Curve II is a plot of the resistivity in the range 20° C. to 1340° C. obtained in measuring the same silver in a container of magnesite 40 parts and alundum 60 parts.

As has been explained in the articles referred to above, the portion of the curve which gives the resistivity in the solid state will be a little too high in the case of those metals which contract upon solidification, as is the case with silver.

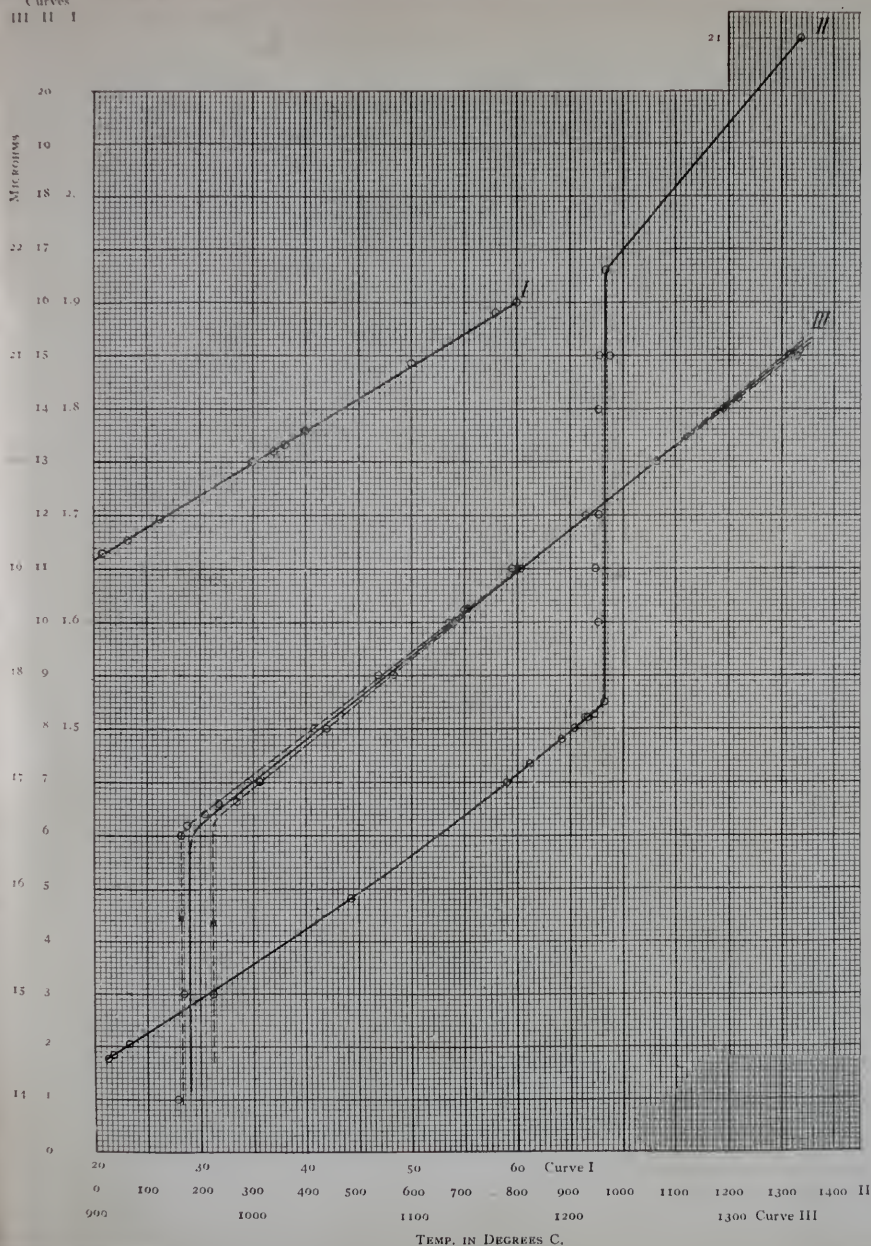
Curve III is a plot upon a larger scale than Curve II of the data obtained for molten silver.

Curve I shows that in the range 20° C. to 60° C. the increase in resistivity with temperature is linear within the limits of accuracy of the measurement. It appears, however, from Curve II that over the wide range 20° C. to 960° C. the resistivity of silver in the solid state gives a curve which is slightly convex toward the temperature axis. The curve is, in this respect, the same as for gold and copper. At the moment of fusion the resistivity suddenly increases (which is the characteristic of all metals examined except bismuth and antimony, which contract on liquefying) from 8.5 to 16.6 microhms.

The resistivity as shown by Curve II before fusion is, however, slightly too great on account of shrinkage in solidifying. Since the resistivity of the wire at 20° C. is 1.65₉, while the value obtained for silver which has cooled in the container is 1.74₉, it is thought that we should call the resistivity just before fusion 8.4. This would make the ratio of the resistivity just after fusion to the resistivity just before fusion 1.98.

The points shown on the curves are those actually obtained. A few points which were in error, for obvious reasons have been omitted. It will be noted in Curve III that the slant of the two dotted lines which give the values obtained with rising and with falling temperature is not quite the same. The cause of this is not known with certainty, but it is supposed to be due to a lag of the temperature of the molten metal behind the temperature of the platinum *vs.* platinum + 10 per cent. rhodium thermocouple used. The heavy line has been drawn as a mean. The departure from the mean at 960° C. is about 0.6 per cent., which may be taken as the probable error in the measurements of the resistivity in the molten state.

The measurement was not carried higher than 1340° C. be-



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cause the thermocouple failed at this temperature, due to the opening of its circuit.

Within the limits of the precision of the measurement, the resistivity of silver in the molten state increases linearly from its melting temperature to the highest temperature measured, 1340° C.

This property which many of the metals have of apparently increasing linearly in their molten state to the highest temperatures at which they have so far been studied has great interest. The writer is now engaged in examining several of the metals in pairs simultaneously to determine if a molten metal, as tin, which melts at a low temperature and boils at a high temperature, may be used to establish the temperature scale far beyond the limits of the gas thermometer. He has so far worked up to 1680° C., using tin and copper, with remarkably concordant results—but this is a matter for a later report.

The following table summarizes the values which have interest relating to pure silver:

Degrees Centigrade	Microhms per centimetre	Ratios, ρ_t/ρ_{t_1}	Remarks
20	1.65 ₉	.....
60	1.90 ₀	.....	Increase per 100° C.=0.60 microhms.
960.5	8.4	.....	Silver solid.
960.5	16.6	$\rho_m/\rho_s=1.98$	Silver molten.
1000	17.01	.....	Temperature coefficient calculated from 1000° C.=0.00069.
1100	18.19		
1200	19.36		
1300	20.54	.....	Increase per 100° C.=1.177 microhms.
1340	21.01		

PALMER PHYSICAL LABORATORY,
Princeton, N. J.

Temiskamite, a New Nickel Arsenide. T. L. WALKER. (*Amer. J. Sci.*, xxxvii, 170.)—Temiskamite has a composition corresponding to Ni_4As_3 . The mineral occurs in calcite veins carrying nicolite and smaller amounts of native bismuth and silver. It is silver-white, with a touch of red, tarnishing very quickly to madder gray. Hardness, 5.5; specific gravity, 7.901; fusibility, 2; lustre, metallic.

The Haze of 1912. ANON. (*Sci Amer.*, cx, No. 6, 112.)—The remarkable turbidity of the atmosphere in the summer and autumn of 1912, with its attendant optical phenomena, has generally been attributed to the presence of dust from the eruption of Mount Katmai, Alaska. However, the question as to the cause of this haze has recently been reopened by Dr. Barkow, who, as a member of Filchner's Antarctic expedition, observed similar phenomena in latitude 70° south, as early as the middle of June 1912, and during some months afterwards. Cirrus clouds of unusual altitude were noted, and the illumination of the northern sky at midday (with the sun below the horizon) was so bright that it was possible to read for several hours. In other words, the phenomena strongly indicated the presence of some light-reflecting substance at an abnormal height in the atmosphere. As it is not thought possible that dust from Katmai could have travelled to the Antarctic so soon after the eruption, Dr. Barkow suggests that the dust was of cosmical origin, though its effects were probably heightened in the northern hemisphere by volcanic dust.

The Kilowatt as the Unit of Power in the Metric System. G. DARRIEUS. (*Lumière Electr.*, xxiv, 336.)—The many advantages are pointed out that accrue from adopting the kilogramme as the standard of mass, and the metre as the unit of length. The unit of force, for example, would be the force that would have to be applied to the mass of 1 kg. in order to give it an acceleration of 1 metre per second. It would, therefore, equal 10^5 dynes. It is suggested that this unit be called the *cop*, from Copernicus. The unit of work in this system would be $10^5 \times 10^2$, *i.e.*, 10^7 ergs or the joule. The unit of power would be the watt. Examples are given to show how engineering calculations would be simplified by adopting the metre-kilogramme-second system.

AN APPARATUS FOR THE SPECTROSCOPIC SYNTHESIS OF COLOR.*

BY

HERBERT E. IVES, Ph.D.,

Member of the Institute,

AND

E. J. BRADY,

Physical Laboratory, United Gas Improvement Company, Philadelphia.

IN the study of the problems of color mixture, and in the practical problem of producing artificial light of a desired color, such as that of daylight, it frequently becomes desirable to have some means of producing at will a light which shall possess identically a chosen energy distribution. For this purpose something more exact than colored absorbing media is desired, for these only by rare chance possess, wave-length by wave-length, the transmission necessary. Even when combinations of these are capable of producing the desired absorption, the task of measuring and combining the various constituent elements is practically prohibitive as a general color-producing proposition. A means is called for which shall make possible and easy the production, for instance, not only of energy distributions derived from spectrophotometric measurements, but also those calculated from formulæ such as the Wien-Planck equation for black bodies at various terrestrially unattainable temperatures.

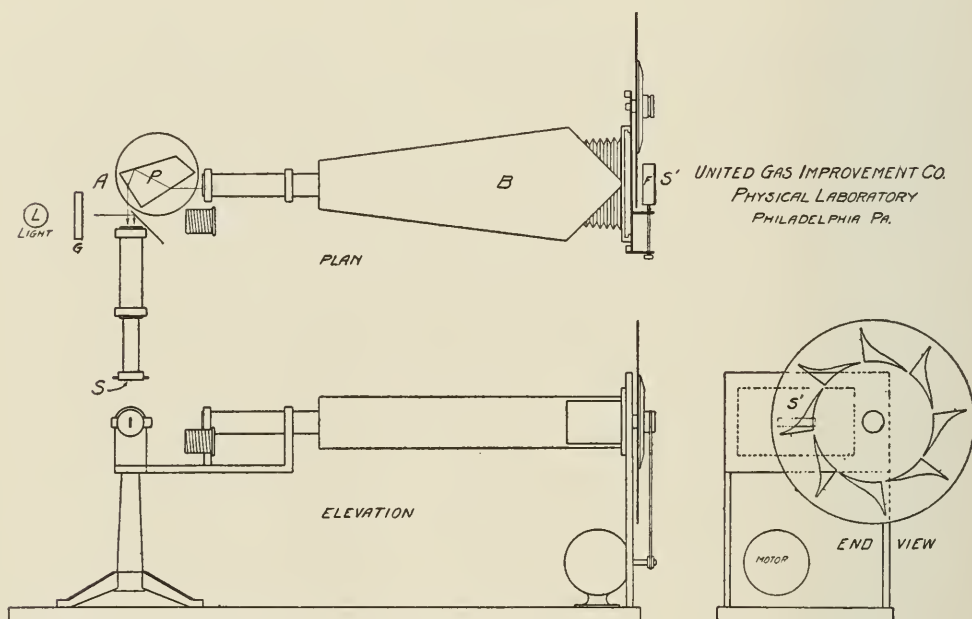
The apparatus here described is similar in principle to one described by Abney in his "Color Measurement and Mixture." It consists of a spectroscope fitted with a revolving disc pierced with openings which act as templates for altering the relative intensities of the various constituent colors of the spectrum of the illuminant used with it. The present instrument is distinctive in employing the principle utilized in Maxwell's color box; that is, the use of an extended area for the source of light, and in being designed as an attachment for a standard laboratory instrument—the Hilger constant deviation spectrometer with photographic

* Communicated by Dr. Ives.

attachment. The principle of the device is best explained by reference to Fig. 1, representing the spectrometer and its attachment.

A is the constant deviation spectrometer and B the camera attachment. As ordinarily used, the light source is placed at the slit S , and an extended spectrum is formed at S^1 . If a convex lens is placed at S^1 , of properly chosen focal length, this spectrum may be recombined and an image of the prism face formed of the same color as the light entering the slit S . If, in addition, at S^1 is placed a neutral tint absorbing screen of different transmission at different points along S^1 , the color of the recombined

FIG. 1.



light can be altered. The most definite and satisfactory way to thus alter the spectrum is by means of a rapidly rotating sector whose openings are of such shape that the various parts of the spectrum are reduced to exactly a desired proportion.

A disadvantage of the apparatus as just described lies in the small amount of light available after this projection and recombination and in the use of more parts than are necessary to achieve the result. A very satisfactory way to use a spectrometer for color work where an extended surface is desirable is to observe the prism face through an eye-slit. This may be done with the present apparatus by simply reversing it. If the opening S^1 be uniformly illuminated by the light source (as

by illuminating the white surface F), then the eye placed at S sees the prism face of the color of the light used. Now, each element of the opening S^1 is virtually a slit forming a spectrum at S ; it is the overlapping of these spectra that gives the integral color. If any of these elements is utilized alone, the prism face is observed of the color that element would receive were the light source at S . In short, the rotating sector or template will affect the color of the prism face in this arrangement just as it would affect the color of the recombined spectrum image before considered. It is only necessary in this case to have an extended uniformly bright source at S^1 , which is easily provided.

With the apparatus as arranged, the next step is to calculate the openings of the sectors. This is done by a series of straightforward steps. First must be known the relative energy distribution of the source available for illuminating F , and of the light it is desired to reproduce. Then, taking into account the dispersion of the prism, which is determined by measuring a line spectrum formed at S^1 (photographically is easiest), the relative opening at each wave-length is determined to perform the desired reduction, and this is reduced to angular units.

In the instrument as constructed by us the spectrometer and camera attachment were firmly screwed on a large, heavy board. The sector was mounted on a separate flat metal plate, which in turn was supported on uprights to the board. The metal plate, pierced with an opening at S^1 , is fastened to the camera body, but in such manner that the latter is under no strain. The motor to turn the sector disc is fastened to the base-board. A small pivoted metal plate F carries the white surface to be illuminated by the standard light source.

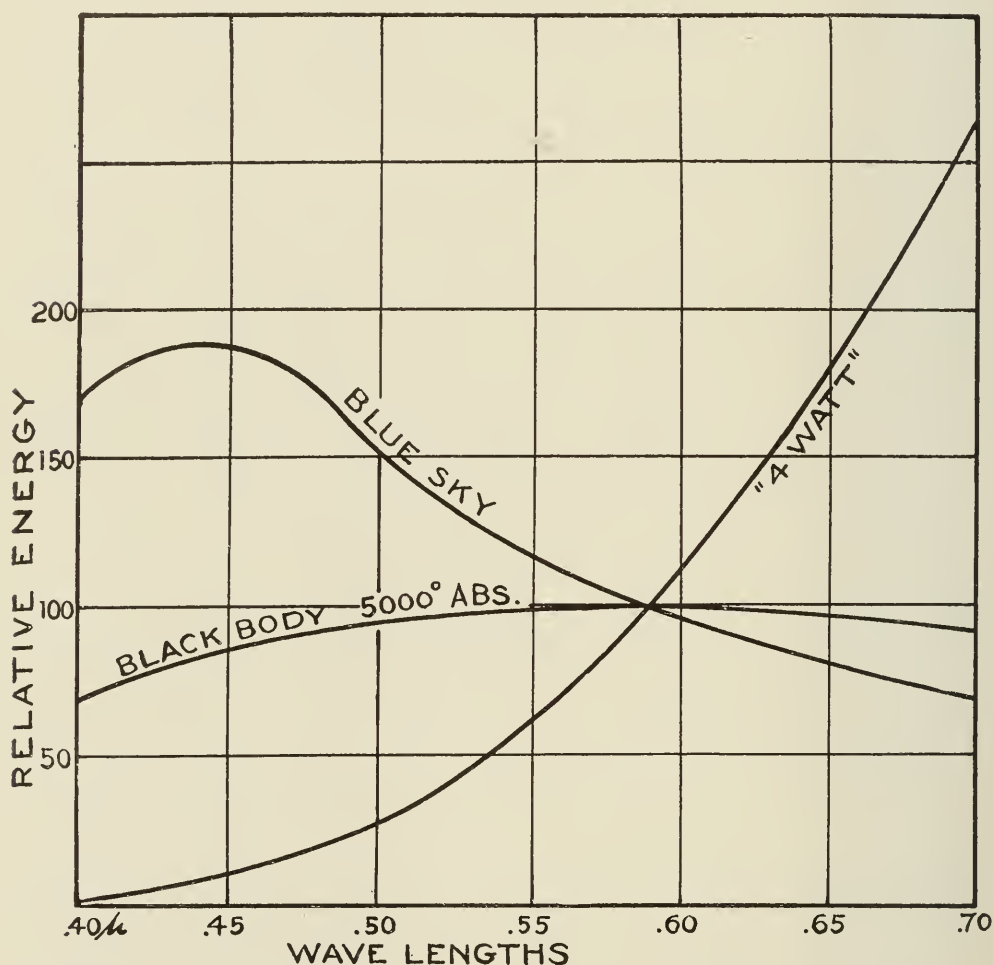
The light source used by us so far has been a 100-candle-power carbon incandescent lamp, accurately matched to the color of the "4-watt-per-candle" lamps used as the photometric standard of this country and maintained by the Bureau of Standards. These lamps were, for reasons given elsewhere,¹ taken as having the relative energy distribution of a black body at 2080° absolute, as calculated from the Wein equation

$$I = c_1 \lambda^{-5} e^{-\frac{14500}{\lambda T}}$$

¹ *Philosophical Magazine*, December, 1912.

Thus far two sector discs have been cut, one to give the light of a "black body" at 5000° (white light) and the other the light of a light blue sky, as determined from spectrophotometer data.² The energy distribution of the 4-watt lamp, the 5000° body, and the blue sky are shown in Plate I, plotted, according to the usual convention, as equal at $.59\mu$. For our present purpose

PLATE I.

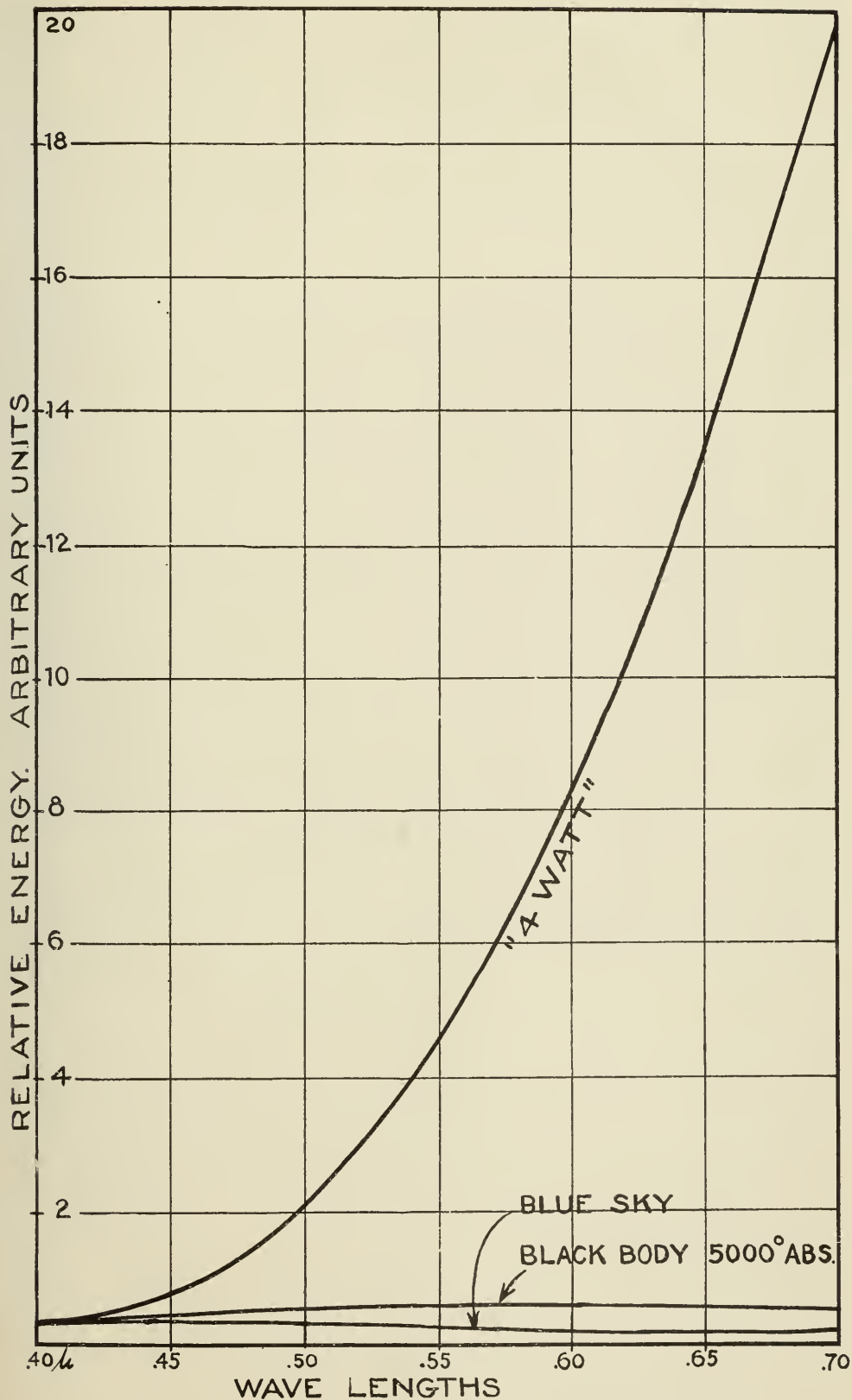


Relative energy distribution, standard "4-watt" lamp, "sunlight" and "blue sky."

they should be replotted as equal to the extreme blue end ($.4\mu$), as is done in Plate II. In this figure the area between the energy distribution curve of the light desired and the 4-watt lamp energy distribution curve represents the energy which must be cut out by the sector. The ratio in this figure of $\frac{\text{energy of desired light}}{\text{energy of standard light}}$

² *Transactions Illuminating Engineering Society*, April, 1910.

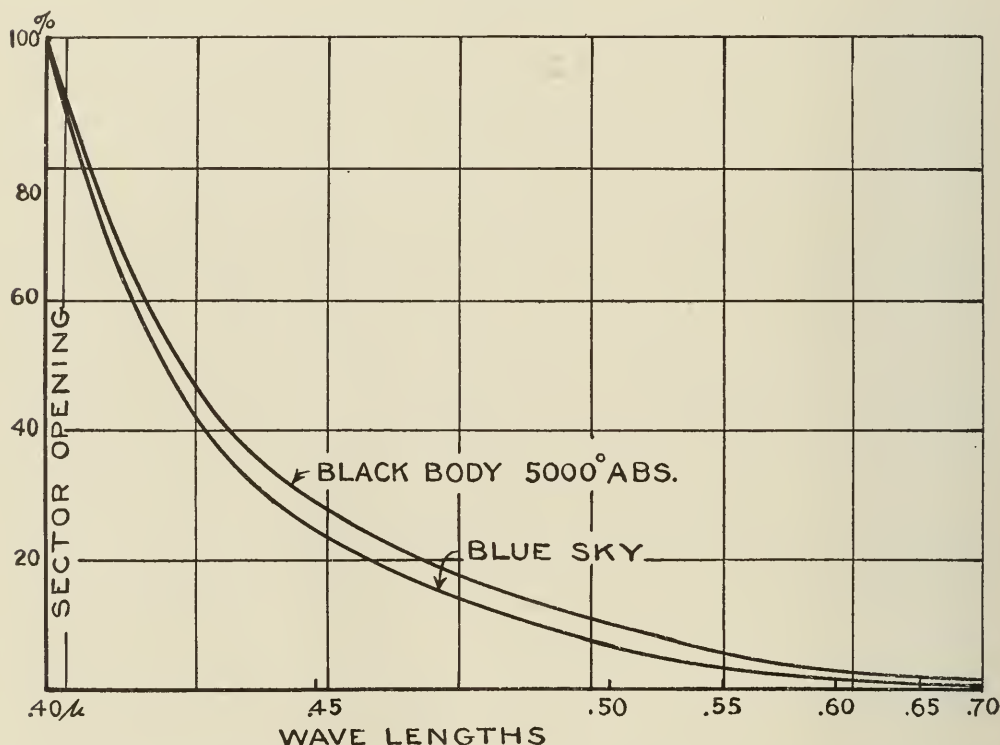
PLATE II.



Relative energy distribution of radiation from standard lamp, black body, at 5000° abs. and blue sky plotted equal as .40μ.

at any wave-length is the opening of the sector at that wave-length. The openings called for are shown in Plate III, plotted on the prismatic scale of the instrument, before being reduced to angular measure. It is advantageous to have the periphery of the disc at the red end of the spectrum, because in reducing to angular units the actual opening at the red end, which is necessarily small, is kept as large as possible in actual dimensions. Each disc has eight openings, each cut in a separate accurately milled sector,

PLATE III.



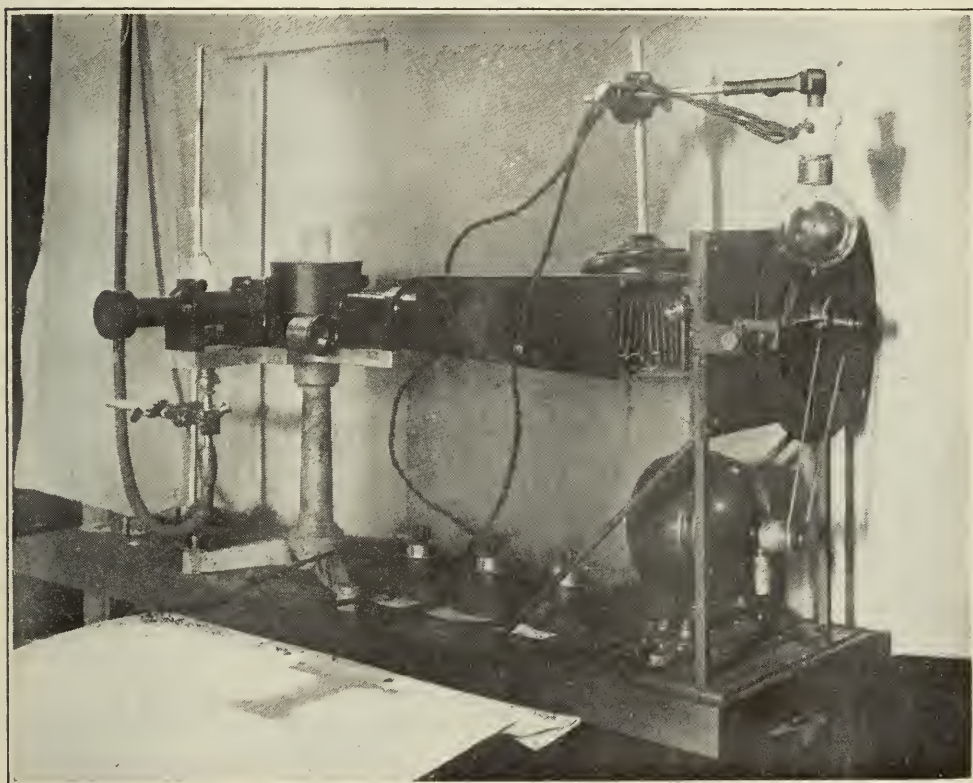
Sector openings to produce "sunlight" and "blue sky." Plotted with regard to the disposition of the prism, but not in angular units.

the sectors being filed to shape over a steel form first laid out with great care, cut, and hardened. A mark is scratched on one of the sectors at the position corresponding to some convenient wave-length, such as the sodium line, so that the apparatus may be easily put in correct alignment at any time by a slight turn of the wave-length drum.

A slight correction necessary to the instrument is that for the selective absorption of the prism. This should be accurately determined and introduced into the calculation of the disc openings.

In our own instrument correction has been provided for so far by the introduction of a block of glass similar to the prism and of the same equivalent thickness on the side of the light being compared with the spectrophotometrically built-up one. This is perfectly satisfactory for the class of work for which the instrument was designed. Future discs will, however, have embodied in them the correction as determined by the spectro-

FIG. 2.



Apparatus for the spectroscopic synthesis of color.

photometer. An instrument using a quartz prism would probably obviate the necessity for this correction, which is negligibly small for most purposes.

Among the uses of the device comes first that for which it was designed, namely, the establishment and preservation of an absolute standard of white light for the industrial production of "daylight glass."³ It should, as well, fill a need that has long been recognized in physiological optics. Such experiments as de-

³ JOURNAL OF THE FRANKLIN INSTITUTE, May, 1914.

termining the "neutral point" of color-blind observers have hitherto been dependent on the use of sunlight or cloud light, of variable and uncertain character. Three-color-mixture and other color-measuring experiments can by this device be put on a far more exact basis than ever before. In fact, the apparatus as described consists practically of one-half of a color-mixture apparatus. For instance, three slits or three incandescent lamp filaments might be arranged on a similar camera body placed at right angles to the one now used, their light being directed by a totally-reflecting prism over half the field through the same dispersing prism and so create a red-green-blue mixture in one half of the photometric field. Ample light can be provided for so that not only spectrum colors but even colored fabrics could be measured by placing them upon F , whereby they would always be illuminated by the same white light. Such improvements over the classical color-mixture devices as measuring the mixing primaries radiometrically suggest themselves. Another possible use of the instrument is in connection with physical photometry. The surface F may be replaced by a long, straight carbon filament, the sectors cut to a "visual luminosity" curve, and the apparatus is ready for the calibration of absorbing media transmissions by pure energy measurements. These and other uses of the instrument will be reported on when the writers have the opportunity to work them out.

Copper Ore. ANON. (*Eng.*, xcvi, 2500, 736.)—Extensive deposits of copper ore have been discovered on the south side of Stora Blasjon, Frostviken, Jämtland, Sweden. The ore is reported to be of high quality and it reaches the surface for distances of as much as 600 feet.

THE PROBLEM OF MOTOR GASOLINE.*

BY
JOHN WINKLER.

CALIFORNIA petroleum is one of the large sources for gasoline, and yet probably 80 per cent. of it is too thick for any explosive mixture and "a sootless burn" in the cylinder. To depolymerize the heavy hydrocarbon oils down to their simplexes—somewhat analogous to the depolymerization of synthetic rubber back to isoprene—the following experiments were carried out:

First, by way of explanation, "cracking" of these oils by mere superheating has proved totally unprofitable in California factories; and so have all kinds of pyrogenic experiments in this laboratory (*i.e.*, passing the vapors with hydrogen through hot tubes containing various metals). The results have not shown promise, as the products go largely into the sludge in refining, and have penetrating odors. The oils show great tendency to thicken when heated, especially in contact with various substances, as air, alkali, concentrated sulphuric acid, and various salts, as aluminum chloride. The best results, of course, are obtained by distillation in an atmosphere of hydrogen. In addition to the unsaturated "cyclic" bodies (chain with closed ends), and the sulphur and nitrogenous compounds, we have considerable benzol ring bodies with side chains—as the mesitylenes—forming the turpentine substitutes. The asphalt, of course, occurs therein as a colloid,¹ and is eliminated at the start by fractional steam distillation.

Experiment 1. *Effect of Corona*.—A glass tube $2\frac{1}{4}$ inches diameter by $3\frac{1}{2}$ feet long, wrapped with wire gauze, with a $\frac{1}{4}$ -inch copper rod suspended co-axially through its centre, was used as a hot vapor chamber, while at the same time the inside rod and outside gauze were kept at a potential of from 25,000 to 30,000 volts by dynamo and high potential transformer. When

* Communicated by the Author.

¹ *Z. Ang. Ch.*, 1913, p. 609.

the room was darkened a continuous bright bluish glow was evident throughout the tube,—*i.e.*, a corona. Through this glow (air removed) various California heavy distillates were distilled repeatedly, with a large excess of hydrogen (dry and moist), the object of the corona being to ionize the hydrogen.² Practically no change could be detected in the oils after repeated slow distillations through the above chamber.³

Experiment 2. *Effect of Arc.*—The Birkeland-Eyde process was applied to these oils in an atmosphere of hydrogen. The oils, both liquid and gaseous, were passed through with increasing speed, to shorten the time in the arc. The carbons were hollow, and hydrogen was passed inward through both. They were kept cool by a water jacket. The results were variable, but in every case the oils were reduced to non-condensable gases and a cloud of fine carbon.

Experiment 3. *Effect of Steam and Aluminum under Pressure.*—Very fine aluminum dust was mixed with various heavy California oils to a “suspension,” and these mixtures subjected to a pressure of 110 pounds per square inch with steam in a heavy, specially constructed machine. They were also agitated, and at the same time heated to various temperatures (indicated by thermometer) up to their cracking points. The purpose of the aluminum and steam was to generate nascent hydrogen within the oil. A variety of attempts indicated no success. The aluminum was not amalgamated.

Experiment 4. *Effect of Reduced Nickel Oxide and Hydrogen on the Aërated Oil.*—According to Charitschkoff, better results at “cracking” Russian petroleum were obtained by first oxidizing the oil.⁴ Heavy California oils were heated, and aërated (by drawing air through them) for two to three days, to oxidize them and to generate petroleum acids (the purpose of this oxidation also being to introduce carboxyl groups, with the possibility of splitting out water with the hydrogen afterwards, and leaving the rest of the broken molecule to unite with the

² The dielectric constants of hydrogen and hydrocarbon vapors and air were found to be not very different.

³ The suggestion of passing SO_2 and air through the above chamber was not tried, but was tried with a large ozonizer with only partial effect. G. Lunge, “Sulfuric Acid and Alkali.”

⁴ “Petroleum,” 1913, p. 748.

excess hydrogen). The aërated oils were subjected to the now well-known hydrogenating process of reduced nickel oxide and hydrogen (said to be least sensitive to sulphur compounds ⁵), but without success. Iodine was substituted for the nickel oxide with no better results.

Experiment 5. *Effect of Rhodium Black and Hydrogen*.—First, active platinum black, made according to the Loew process,⁶ has been shown to be a good catalyst to hydrogenate pure benzol and pure benzine. It is, however, poisoned by sulphur bodies.⁷ The work was corroborated in this laboratory perfectly, but California oils contain sulphur, and so do not hydrogenate.

Second, G. Bredig has shown that rhodium metal acts as a catalyst to break down formic and acetic acids to H and CO₂, etc., and that sulphur bodies are favorable to its activity.⁸ Rhodium black was made (by the Loew process), and tried out on California oils under parallel conditions, but failed to hydrogenate in the least.

An easy experiment which is suggested here is to find a possible antidote for the poisonous effect of sulphur bodies in benzol on platinum black. Could we hydrogenate the oils, it is obvious that they would then depolymerize more readily.

UNIVERSITY OF CALIFORNIA, May, 1914.

⁵ *Z. Ang. Ch.*, 1913, pp. 561-606.

⁶ *Ber.* 23, p. 289.

⁷ *Ibid.*, 45, p. 1471 *et al.*

⁸ *Oest. Ch. Ztg.*, No. 14 (1911), p. 266.

Russian Platinum Production in 1913. (*Board of Trade J.*, March 19, 1914.)—H. M. Commercial Attaché for Russia reports that the yield of platinum in the Urals continued to decrease during 1913 in spite of the very high prices prevailing. According to the *Torgovo-Promyshlennaya Gazeta* (St. Petersburg) of February 24th, the production in 1913 was 299 pouds 18 funts, as compared with 337 pouds 9 funts in the previous year. (Forty funts = 1 poud = 36 pounds.)

The Deformation of Water Conduits. C. GUIDI. (*Accad. Sci. Torino*, atti xlviii, 357, 1912.)—Considers the deformation of an iron tube having a wall thickness of $0.02 r$ or $0.01 r$ where r is the radius of the iron tube. The conduit is assumed to be supported over an arc of 40° , offering a uniform resistance. The deformation is due partly to the hydrostatic pressure and partly to the weight of the water. If r is 100 cm., a tube 2 cm. thick shows very small deformations; but when the thickness is only 1 cm. the limits of stability are approached.

The Experimental Gallery at Derne, Westphalia. BEYLING and ZIX. (*Glückauf*, xlix, 433.)—The natural gas used in the explosion tests in the experimental gallery which was established at the Consolidation Colliery in 1896 having become exhausted, a new gallery has been erected at Derne, near Dortmund, where natural gas can be obtained containing 88.9 per cent. methane, 9.3 per cent. nitrogen, 0.9 per cent. carbon dioxide, and 0.9 per cent. oxygen. The main gallery is built up of boiler plate; it is circular in section, 1.8 metres diameter; present length, 100 metres, to be extended to 300 metres. The smaller gallery is elliptical in section, 1.83 metres high, 1.32 wide, and 25 metres long; it is built up of three layers (six in exposed parts) of tarred pitch pine boards lined inside with sheet iron and bound outside by half-rings of I-iron; the one end is closed by a block of brickwork, through which the ventilator pipe is carried; like the main gallery, it is provided with observation windows. There is, further, a third gallery, 4 metres by 1.8 and 1.4 metres, for special experiments, and an iron conduit for safety-lamp testing by Schondorf's method. A magazine for explosives is near. The plant is described, but no new experiments are yet mentioned.

Combined Neon and Mercury-vapor Tubes. ANON. (*Electr. Engineering*, x, 23.)—In the arrangement as applied by G. Claude neon and mercury-vapor tubes are successively lighted and extinguished, so that, owing to the condensation of the mercury-vapor by cooling, red, blue, and other colored lights are obtained.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

[ABSTRACT.]

OBSERVATIONS ON FINISHING TEMPERATURES AND PROPERTIES OF RAILS.*

G. K. Burgess, J. J. Crowe, H. S. Rawdon, and R. G. Waltenberg,
Bureau of Standards.

THE main objects of this investigation were to determine, from measurements taken in representative rail mills, the present American practice regarding the temperatures at which rails are rolled; to demonstrate the ease and accuracy with which such temperatures may be measured; to find out what the "shrinkage clause" in rail specifications really means; and, finally, to determine for rail steels some of the physical properties, particularly those of interest in manufacture.

Observations were taken with an optical pyrometer of ingot and finishing temperatures of rails in four representative mills.

There is practical uniformity among the several mills for the rolling temperatures of ingots for steel rails, the range being from 1080°C. (1975°F.) to 1140°C. (2085°F.). There is no very considerable difference among the finishing temperatures of the rails as observed at the hot saws for several mills, the range being about 880°C. (1615°F.) to 990°C. (1815°F.), or, in other words, the four mills all finished their rails to within 50°C. of 935°C. (1715°F.) on the average. This temperature of 935°C. is 270°C. (520°F.) above the mean value, 665°C.

* This is a summary of a paper to be published shortly in full as a *Technologic Paper* of the Bureau of Standards with the following contents: 1. Introduction; 2. Importance of Limiting Temperatures of Rolling Rails; 3. Methods of Measuring Rail Temperatures; 4. Wickhorst's Experiments; 5. Measurements of Ingot and Finishing Temperatures; 6. The Samples and Chemical Analyses; 7. Mechanical Properties of Rails; 8. Melting Temperatures of Rail Steels; 9. The Critical Ranges of Rail Steels; 10. Observations on the Microstructure; 11. Temperature Distribution in a Cooling Rail; 12. The Expansion of Rail Steels; 13. The "Shrinkage Clause" in Rail Specifications; 14. Summary and Conclusions.

(1230° F.) of the critical ranges of these rail steels. Concerning the distribution of temperatures within the head of a cooling rail, it is shown that the centre of the head is some 50° C. (120° F.) to 60° hotter than the optical pyrometer reading at 935° C., therefore the centre of the head is finished, on the average, at about 325° C. (615° F.) above the critical range for 100-pound sections.

Chemical analyses and microphotographic examinations were also made and the mechanical properties determined for a number of samples of rail the rolling of which had been observed. From a comparison of these few observations there appears to be not a sufficient degree of correlation to warrant associating very specifically any of the characteristics defined by these three methods of examination, either with the temperatures of rolling here observed or with each other.

The following thermal properties of these rail steels were determined in the laboratory:

The critical range on heating is located (maximum) to within 7° C. of 732° C. (1350° F.) for the 10 samples of O.H. and Bessemer steels examined. On cooling, the critical range lies between the limits 680° C. (1256° F.) and 650° C. (1202° F.).

The melting or freezing range for rail steel extends from about 1470° C. (2680° F.) to nearly the melting-point of iron, located at 1530° C. (2786° F.).

The expansion for O.H. and Bessemer steels is not the same. Above 800° C. (1470° F.) the expansion for both increases linearly with temperature, and the linear coefficient per degree centigrade has the following mean values from 0° to 1000° C.:

(1) For Bessemer steel (carbon .40 to .50%): $\alpha = 0.0000146$ to

(2) " open-hearth " (carbon .65 to .75%): $\alpha = 0.0000156$ to 0.0000161

The average composition of the Bessemers was carbon = 0.40 to 0.50 and manganese = 0.76 to 0.93; of the open-hearths, carbon = 0.66 to 0.70 and manganese = 0.66 to 0.72.

The American Society for Testing Materials in 1909 limited the shrinkage allowance on 100-pounds sections to $6\frac{3}{4}$ inches in 33 feet, or to an equivalent of 1947° F. (1064° C.) for O. H. and 2055° F. (1124° C.) for Bessemer rails. This specification is still in force. Such a shrinkage clause therefore does not

serve the avowed purpose of limiting the finishing temperatures to a value slightly above the critical range.

In conclusion, it should be emphasized that the various series of observations recorded in this investigation are of but a preliminary nature and do not pretend to solve the question of the relations between temperature of rolling and the properties of rails. It would seem desirable to make a much more complete and comprehensive study of the various matters mentioned and of related questions than has hitherto been attempted, and on a scale commensurate with the importance to the community of the problem of sound rails.

[ABSTRACT.]

THE ANALYSIS OF PRINTING INKS.

By J. B. Tuttle and W. H. Smith.

A PROCEDURE of analysis of printing inks has been developed which, during the years in which it has been used, has been found to be very satisfactory.

By means of suitable solvents, the ink is divided into two parts: oil and pigment.

The oil fraction is analyzed for unsaponifiable matter and rosin. The former may consist of mineral oils or the hydrocarbon portion of rosin oil. A qualitative test for rosin oil and rosin is given.

The analysis of the pigment fraction will depend very largely on the color of the pigment. Methods are given for the determination of the principal constituents of the more common inks, such as black, red, blue, green, etc.

The paper contains a brief discussion of the relation of aniline dyes in the inks to the paper. This covers the question of the permanency of the blue dyes used to neutralize the yellow color of the oil, and emphasizes the necessity for a careful selection of the dyes to be used. Several methods for the determination of the permanency to light of the various colored pigments are given.

A few special tests for some abnormal constituents of ink are given. They are not considered to be very important.

Figures are given showing how closely one may expect duplicate determinations on the same sample to check, based on the experience of this Bureau during the past two or three years. It is claimed that these checks are at least as close as the manufacturer can duplicate his ink, and may therefore be considered satisfactory for practical purposes.

Fuller's Earth.—A report on fuller's earth, by Jefferson Middleton, of the United States Geological Survey, has been published as a chapter from "Mineral Resources" for 1913, and copies will be sent to interested persons free, on application to the Director of Survey at Washington, D. C. The value of the fuller's earth mined in 1913 in the United States was \$369,750, against \$305,522 in 1912, an increase of \$64,228. The production in 1913 was but \$13,374 less than that of 1911, the year of maximum production. In quantity and value of production Florida was the leading State in 1913, Georgia was second, Arkansas was third, and Massachusetts fourth. Florida and Georgia together contributed over 97 per cent. of the quantity and value of the fuller's earth marketed in 1913.

The Operation of the Panama Canal Locks. ANON. (*Eng. News*, lxx, 1323.)—A large amount of power is used, at different points along the canal, and this article chiefly treats with the methods employed to control the various operations, to record the various water levels and to interlock different devices. At the Gatun dam there is a 7500 kv.a. 2200-volt hydro-electric generating station; at Miraflores there is an emergency station of about half the size. A two-circuit 44,000-volt transmission line runs across the Isthmus. A large amount of power is used at various points for working the locks, for lighting, power, and traction. The scheme of connection throughout uses a double bus-bar with duplicate oil switches so that one can be disconnected for cleaning or repair. There are in all 36 substations at different points.

THE FRANKLIN INSTITUTE

AWARD OF THE ELLIOTT CRESSON MEDAL TO DISTINGUISHED SCIENTISTS AND TECHNOLOGISTS.

At a stated meeting of the Institute, held on the evening of Wednesday, May 20, 1914, Dr. Walton Clark, President of the Institute, presiding, the Institute's Elliott Cresson Medals were awarded to:

PROVOST EDGAR FAHS SMITH, PH.D., SC.D., LL.D., in recognition of his leading work in the field of electrochemistry, of his many contributions to the literature of chemical science, and of his great service in university education.

ORVILLE WRIGHT, B.S., LL.D., in recognition of the epoch-making work accomplished by him, at first together with his brother Wilbur and latterly alone, in establishing on a practical basis the science and art of aviation.

PROF. KARL PAUL GOTTFRIED LINDE, PH.D., in recognition of his scientific investigation of the processes of refrigeration and the liquefaction of gases, and of his inventions of machinery for applying these processes in the manufacture of ice and for the purposes of cold storage.

JOSEF MARIA EDER, PH.D., in recognition of his important original researches in the science of photo-chemistry and of his many valuable contributions to the literature of that science and of graphic arts.

The work of Drs. Smith and Wright was described by Dr. Harry F. Keller, who presented them to the President of the Institute, from whom they received the medals awarded them. The work of Drs. Eder and Linde was described by Mr. Louis E. Levy.

In opening the meeting, the President of the Institute, Dr. Walton Clark, said: This is a stated meeting of The Franklin Institute. We are honored by the presence of two gentlemen to whom the Institute authorizes and instructs us to present the Elliott Cresson Medal in recognition of their distinguished work of science. The Chair recognizes Dr. Keller to present Dr. Edgar Fahs Smith, Provost of the University of Pennsylvania, for the Elliott Cresson Medal.

DR. KELLER: Mr. President, the Committee on Science and the Arts has once more scanned the rolls of our contemporaries who have attained eminence in the field of pure and applied science which this Franklin Institute of ours has always striven to promote, and in choosing and recommending the names

of the Elliott Cresson Medallists of this year the committee was confident that they would be accepted as in every way worthy of being ranked with those on which this honor has been conferred in former years.

Of the four scientists and inventors to whom this highest award of the Institute has been made in accordance with the committee's recommendation, two are Europeans, while the other two are of our own nationality. All four of the medallists have expressed their gratification and appreciation in accepting the award, and our two distinguished compatriots are giving us the pleasure and the honor of their company to-night in order that they may receive the medals from your hands. And in both instances the presence of the recipient is attended with a circumstance that much enhances our joy in the welcome we extend to him; in the one, our guest is a fellow-townsmen and, I believe, the first on whom the Elliott Cresson Medal has ever been bestowed for his life-work; while in the other a busy inventor paused in his work and made the long journey from Dayton, Ohio, to be present on this occasion.

Mr. President, the work of the scientific investigator and of the director of a great university laboratory may be lacking in the picturesque and dramatic features, and, as a rule, is not calculated to arouse popular attention and enthusiasm, but, nevertheless, it not infrequently yields results of the highest value, not only in adding to the sum of our knowledge, but also in promoting the material welfare of mankind. It is no exaggeration to say that there are few inventions that minister to our needs and comforts in which advantage has not been taken of scientific work, the primary purpose of which is to establish truth for its own sake. Thus the marvellous growth and development of the electrical industries was made possible only through the great discoveries made by investigators like Faraday and Henry; and the resplendent triumphs of modern synthetic chemistry had their source in the researches conducted by such master-minds as Liebig, Hofmann, and Emil Fischer. It is the quiet work steadily going on in the laboratories of our institutions of learning that is the main-spring of the rapid advances in our industries and manufactures. The prominent part which chemical research has had in the development of our natural resources is clearly reflected in an interesting volume just published, from the pen of one of our medallists. Its title is "Chemistry in America," and it tells in a fascinating manner of the achievements made by American chemists during the first century of our national existence. With characteristic modesty, however, the author has refrained from including in this account the splendid work which he and his students have done in the nearly four decades that have since elapsed. It was my good fortune to witness, first as a student, then as an associate, and later as an interested spectator, the uninterrupted chain of beautiful and valuable researches he conducted during this long period, for the most part in the chemical laboratory of the University of Pennsylvania. The results of this work are recorded in more than 150 contributions to the principal periodicals devoted to chemistry, and in a number of books. The earlier publications were mostly on synthetic-organic and mineralogical subjects, but gradually

these were abandoned in favor of more original and more extended lines of work which led the enthusiastic investigator into new or neglected fields of inorganic chemistry. In the brief space of time allotted to me it is impossible to attempt even the merest sketch of these fruitful researches. The most important of them may be classed under four heads, viz., electrochemical analysis, the rarer metals, the complex inorganic acids, and the determination of atomic weights. In electrochemical analysis our medallist now stands *facile princeps*; for not only was he one of the pioneers in this branch, but he has assiduously and indefatigably continued its cultivation. We are indebted to him for a great number of excellent electrolytic methods, for some of the most serviceable forms of apparatus used in such work, and for a standard text-book on the subject. The researches on the rare elements and the complex inorganic acids have yielded innumerable interesting and important results, and thus greatly added to our knowledge of subjects which only the most resourceful of experimenters can venture to attack. The same is true also of the determination of atomic weights; indeed, it is one of the proudest achievements of our medallist that his extended work in this direction has yielded so many values which closely approach, and in some cases exactly agree with, the now accepted standards of these natural constants.

It is my understanding, Mr. President, that the Elliott Cresson Medal is awarded for the eminent services the recipient has rendered to chemical science as an investigator, and I must for this reason refrain from referring to his no less distinguished activities as a teacher, as an author, as a leader of men, and as the revered Provost of one of our greatest universities. But I am sure that is quite unnecessary before an audience such as this.

It is with very great pleasure that I have the honor of presenting to you the eminent chemist, Provost Edgar Fahs Smith, of the University of Pennsylvania.

DR. CLARK: Dr. Smith, in the name of The Franklin Institute, moved thereto by its Committee on Science and the Arts, and in recognition of your distinguished services to mankind rendered in the field of science, I have the honor to present to you the Elliott Cresson Gold Medal, the highest honor in the gift of the Institute.

DR. CLARK: The Chair again recognizes Dr. Keller to present Dr. Orville Wright for the Elliott Cresson Medal.

DR. KELLER: Mr. President, the past two decades have been prolific in achievements which in former times would have been considered as quite beyond the range of human endeavor. Problems which had been abandoned by investigators and inventors because of apparently unsurmountable difficulties have not only been successfully solved, but the popular mind has become so familiar with the results that these are no longer regarded as wonders.

To mention but a few instances we think nothing of ordering a taxicab by wireless message as our liner approaches port; the liquefaction of what we used to call the "incoercible gases," such as atmospheric air, is rather a

tame and commonplace performance now; we have ceased to worry about the exhaustion of the Chilean nitre deposits since the fixation of atmospheric nitrogen has been made a commercial success; moving pictures must be in natural colors and accompanied by speech or song to arouse special interest; and nothing short of crossing the Atlantic will now suffice to demonstrate the high degree of proficiency that has been attained in aërial navigation.

Nevertheless, it is true that of all inventions of modern times none has aroused greater curiosity, none taxed the ingenuity, the endurance, and the daring of men in a higher degree than the conquest of the atmosphere. Through the ages men had dreamed of a mechanism that would enable them to soar and simulate the flight of birds. From the cunning Dædalus of old down to our own times innumerable attempts to accomplish this most alluring aim have been recorded. It was not, however, until the beginning of this century that the mechanic arts had advanced sufficiently to permit its realization. Valuable pioneer work in gliding flight had indeed been done by those ill-starred enthusiasts, Otto Lilienthal, of Germany, and Percy Pilcher, of England, as well as by our own Octave Chanute; and the possibility of mechanical flight in a heavier-than-air machine had been foreshadowed by the experiments of Langley. But the construction of an apparatus that was capable of carrying a man and of being steered in every direction is an achievement that must be credited to the genius and the undaunted energy of two brothers, natives and citizens of the state of Ohio. Beginning in 1900, they conducted a series of experiments, extending over nearly three years, on the undulating sand-dunes near the Kitty Hawk Lighthouse, N. C. Among other results this work led to the invention and development of two essential features of the aëroplane, viz., the front horizontal rudder for steering in a vertical direction, and the device for balancing the machine in flight by flexing the outer ends of the supporting planes. In the meantime the gasoline engine for automobiles had been so far perfected that with suitable adaptation to the aëroplane it enabled the inventors to design a machine combining relatively high power with low weight and capable of carrying a man in flight. The first successful flights with such an aëroplane were made in December, 1903, and each of the brothers in turn was at the helm. But shortly after landing from a flight of nearly a minute's duration and extending over 852 feet the plane was caught in a wind-gust and completely wrecked. The possibility of mechanical flight, however, had been demonstrated, and, as is well known, the aëroplane has since that time been vastly improved in power, speed, endurance, and safety. Men of many nations have had a share in this truly wonderful evolution, but among them the original inventors were always in the forefront.

The one great desideratum that still remains is perfect safety under all conditions, and to this end the medallist of the evening is bending all his energies; so that flying shall become as safe as the usual means of locomotion on land and sea. For this crowning triumph of aviation we look with confidence, Mr. President, to the great inventor and intrepid aviator. I have the honor of presenting to you Doctor Orville Wright.

DR. CLARK: Dr. Wright, in the name of The Franklin Institute, moved thereto by its Committee on Science and the Arts, and in recognition of your distinguished services to mankind rendered in the field of science, I have the honor to present you with the Elliott Cresson Gold Medal, the highest honor in the gift of the Institute.

DR. CLARK: The Institute has awarded the Elliott Cresson Medal to two other distinguished gentlemen, not residents or natives of America—Dr. Josef Maria Eder, Imperial Court Councillor of Austria, of Vienna, Austria, and Dr. Karl Ritter von Linde, of Munich, Germany. These gentlemen have written in appreciation of the distinction conferred upon them by the Institute, and regretting their inability to be present to personally receive the medals. Their absence shall not rob us of the opportunity of hearing something of them and their work, however, and to this end the Chair recognizes Mr. LEVY.

In presenting the work of Dr. Eder, Mr. Levy said: Mr. President, it has been said that the art of printing is the art preservative of arts, and in the same spirit it may be said that photography is the art preservative of nature. For no formula of words, however accurate and detailed, can preserve the semblance of an object of any kind so perfectly as a picture, and no picture can be as true to nature as a photograph.

The art of photography has become not only a method of portraiture, a means of preserving a record of appearances, but also a potent factor in the dissemination of intelligence, a vehicle of popular instruction, an agency in widening the compass of the æsthetic arts and of raising the culture level of the masses of the people. So universally has the product of the photographic art, in all the ranges from the picture post-card to the moving-picture show, become a feature of our modern life, that, in distinction from those earlier stages of civilization which we recognize as the Stone Age, the Age of Bronze, the Iron Age, our present epoch might fittingly be characterized as the Pictorial Age.

The beginnings of the modern graphic arts date back to the tentative efforts of scientists and experimenters over a century ago, which were continued and amplified by their successors during the first half of the nineteenth century. But it has been only within the period of the passing generation that the advances made in photo-chemical science have opened the way to that progress of the art which is spreading its products through all the countries on the globe. This progress, through a combination of the camera and the printing press, has in turn given rise to that great expansion of the pictorial art which is so manifest on every hand in the form of illustrated newspapers, magazines, and books, and which has given the graphic art industry not only a place as an educational agency, but also brought it to a position of great economic importance.

Many workers in every land of civilization have contributed each a share in widening the field of the photo-reproductive arts, some through their researches in photo-chemistry, others through advances in the application of that science. A large and in many respects a peculiarly significant share in

both directions has been contributed by an eminent photochemist in Austria, Dr. Josef Maria Eder, Director of the Royal-Imperial Institute for Research and Instruction in Photography, established in Vienna. That institution, founded by Dr. Eder, under the auspices of the Austrian government fifteen years ago, soon achieved, and under his direction has retained, a leading position as a centre of photochemical science and technology in continental Europe.

Dr. Eder has been identified with the progress of the graphic arts throughout the period of their contemporary development. His contributions to the literature of photo-chemistry date from 1876, when he was but 21 years old, and from that time to the present his researches have been fruitful of many important additions to the science of photography, and the result of his investigations, freely given to the world through his books and through his writings in periodical literature, have greatly furthered the progress of the art.

The Committee on Science and the Arts of the Institute, fully cognizant of the service which has thus been rendered toward the upbuilding of the modern graphic arts, recommends to the Institute that the Elliott Cresson Gold Medal be awarded to Court Councillor Dr. Josef Maria Eder, of Austria, in recognition of his distinguished leadership in that direction.

In presenting the work of Dr. Linde, Mr. Levy said: Last Friday evening The Franklin Institute, together with a number of other technological societies, joined in a meeting at which the principal topic of discussion was the influence which science, invention, and engineering had exerted, and continued to exert, in the development of modern civilization. As was so clearly pointed out on that occasion, this development has inevitably been attended by an increasing complexity of our modern life, which, in its turn, has reacted to present new problems which science has been called upon to solve, new requirements which the inventor has been called upon to meet, and new complexities which the scientific engineer has been called upon to adjust.

Not the least important, and perhaps the most pressing, of these requirements has been that of adjusting the food supply of cities to meet the exigencies which have arisen along with our modern system of coöperation in industry and the coincident growth of great centres of population. To this end it became necessary to store food products in large quantities at convenient points and to preserve these products from decay during storage before their final distribution. Refrigeration was clearly the most desirable method for the purpose, but the problem in this case was not only to produce the necessary low temperature on a sufficiently large scale, but to accomplish this at a cost within the limits of commercial practice. This all-important need was early sought to be met by inventors on both sides of the Atlantic, but remained to be solved by a scientific engineer in Germany, Karl Paul Gottfried Linde. As far back as 1870, while Professor of Engineering at the Technical High School in Munich, Dr. Linde, through his study of thermodynamics applied to refrigeration, pointed the way to the desired end, and in the course of that decade, through the application of great in-

ventive skill and indefatigable industry, he succeeded in developing the ammonia process of ice making and in completing the machinery for the purpose. Dr. Linde was the first to produce ice on a commercial scale, and has been largely instrumental in developing the cold-storage practice of the present day.

Through Dr. Linde's system of regenerative refrigeration, the means were accorded for the liquefaction of the permanent gases, including not only air but also oxygen, and even helium. He was the first to produce liquid air by continuous process and on a large scale, and by a modification of this process he has made possible the economic production of oxygen for practical purposes.

The Committee on Science and the Arts of The Franklin Institute, availing itself of an occasion to testify its high appreciation of the work which I have here but briefly indicated, recommends to the Institute that the Elliott Cresson Gold Medal be awarded to Professor Doctor Karl Paul Gottfried Linde for his leading and directive work in the science and art of refrigeration.

DR. CLARK: The medals awarded to these distinguished European scientists will be forwarded to them through our State Department at Washington.

The medallists who are with us this evening have consented to address us on subjects with which they are, among all men, most familiar.

I take pleasure in introducing Dr. Edgar Fahs Smith, who will speak on the subject of "SCIENTISTS FROM THE KEYSTONE STATE."

DR. SMITH: Before reading the few paragraphs which I have on these pages, I feel that I must express to you here publicly my sincere thanks for the honor which you and the Institute you represent have shown me to-night. If the work I have done has merited this recognition from your hands, then, sir, I feel it incumbent upon me to say that that work could not have been performed without the hearty coöperation, the encouragement, and the sympathy of my students, many of whom are in this audience this evening, and among them Dr. Keller, who so kindly presented me to you for this honor.

(Dr. Smith here read an able paper, in which he reviewed the accomplishments of the State's most noted scientists.)

DR. CLARK: Dr. Smith tells us that Pennsylvania has produced notable men of science, and Dr. Smith knows; and that she is still producing notable men of science, and that their voices are still heard in this Hall, you have just witnessed.

I have now great pleasure in introducing Dr. Orville Wright, who will speak to us on the "STABILITY OF AËROPLANES."

DR. WRIGHT: It is with feelings of deep appreciation that I receive from The Franklin Institute its Elliott Cresson Gold Medal in recognition of work done in the advancement of the art and science of aviation. It is the more gratifying because it is in part given in recognition of work done by my brother Wilbur when we were associated together. I prize the medal highly, and wish to express to the Board of Managers and to the members of the Institute my sincere appreciation.

(Dr. Wright here delivered his address, treating of several phases of the control of the fore and aft balance of flying machines. Dr. Wright's address will appear in a later number of the JOURNAL.)

DR. CLARK: The Institute has been favored, and the JOURNAL OF THE INSTITUTE will be enriched, by this remarkable presentation of the problems involved in the work of Dr. Wright and his distinguished brother.

In the name of the Institute I thank the gentlemen for their interesting lectures.

Brief biographical sketches of the recipients of the medals are given below:

EDGAR FAHS SMITH.

EDGAR FAHS SMITH, PH.D., SC.D. LL.D., was born at York, Pennsylvania, on May 23, 1856. He was graduated in science from the Pennsylvania State College in 1874, and two years later was made Doctor of Philosophy at Göttingen. He was instructor in chemistry at the University of Pennsylvania from 1876 to 1881, and for the two following years was professor in chemistry at Muhlenberg College. He was then appointed to the chair of chemistry at Wittenberg College, which he occupied until 1888. In that year he was called to the University of Pennsylvania, and has held the chair of chemistry since. In 1899 he was made vice-president and in 1910 was elected provost of the University.

Professor Smith's investigations in the field of inorganic chemistry are most remarkable for their great number, the wealth of new results and the wide range of subjects. He ranks easily first among those who have studied the electrochemical methods of analysis; his treatise on this subject is a standard work; and his methods and apparatus are universally used. He has also made numerous important contributions to our knowledge of the atomic weights of the elements, of the various groups of complex inorganic acids, and of the processes used in the separation of the rare earths. He has also devised and improved a considerable number of analytical methods. As author or translator of textbooks he has given to the English-speaking students and chemists a number of valuable and popular manuals, and he has also written most interestingly on subjects of historical chemistry. As the Director of the Harrison Laboratory of the University of Pennsylvania he has trained a great number of successful chemists and chemical engineers.

JOSEF MARIA EDER.

JOSEF MARIA EDER, PH.D., son of Austrian District Councillor Josef Eder, was born at Krems on the Danube, March 16, 1855. Educated at the Technical High-School in Vienna, he devoted himself from his boyhood to the study of the then-budding science of photo-chemistry, and soon distinguished himself by his successful efforts in largely furthering its progress. As early as 1876 he began those numerous contributions to current photographic literature which he has continued to the present time. In 1878 he published the results of his investigations on the "Reactions of Chromic Acid and the Chromates on the Gelatines, Gums, and Sugars," a work which

opened wide the field of study in this direction and which was awarded the prize of the Vienna Photographic Society. In 1879 he published his work on "The Influence of Colored Light on Photography in Natural Colors." In that same year he was appointed lecturer on photo-chemistry at the Technical High-School, and obtained there his academic degree in 1880. While serving in that institution he carried through a series of important researches, the results of which were published in various forms. Especially notable among these results are those presented in his book, published in 1881, on "The Theory and Practice of Photography with Gelatino-Bromides and Iodides," and that of 1883, on "The Chemical Effects of the Spectrum." In 1882 he was accorded the professorship of chemistry at the State Industrial School in Vienna, but he continued without interruption his frequent contributions of important scientific data to the current periodical literature of photography. In 1887 Dr. Eder began the publication of his Year Book of Photography, now universally known as Eder's Jahrbuch, a work he has continued to the present time, steadily advancing it to greater thoroughness and completeness. This annual has gained general recognition as a comprehensive chronicle of the world's progress in the science of photo-chemistry and its practical applications, and presents a most valuable addition to the literature of the graphic arts.

In 1888, under the auspices of the Austrian Government, Dr. Eder organized the now famous Vienna Institute for Instruction and Research in Photography, of which he became, and still remains Director, and which has formed the model for similar schools in Germany, France, and England. The results of his investigations at the Institute have been given to the world in his work on "Photography with Röntgen Rays," published in 1896; that on "Photo-chemistry and Spectrum Analysis," in 1903; his "Atlas of Typical Spectra," 1912; and in that monumental work, his "Complete Handbook of Photography," in four volumes, of which a fifth edition was issued in 1912.

Dr. Eder is Royal-Imperial Court Councillor of Austria, Officer of the Legion of Honor of France, Commander of the Francis Josef Order, of the Swedish Order of Wasa, of the Albrecht Order of Saxony, and so forth,—honors which but reflect that which he has earned through his work.

KARL PAUL GOTTFRIED LINDE.

KARL PAUL GOTTFRIED LINDE, PH.D., was born in Berndorf, Oberfranken, on June 11, 1842. From 1866 to 1868 he was director of the construction department of Krauss and Company's Locomotive Works Munich, Bavaria. In 1868 he was appointed assistant professor at the Technical High-School, Munich, and three years later professor. From 1879 to 1890 he was manager of the Linde Ice-Machine Company.

He was the pioneer in the manufacture of ice on a large scale, and in the introduction of liquid ammonia as the refrigerant in ice machines and cold-storage systems. The refrigerating machinery mostly used at the present time, known as the ammonia "compression" system, is essentially Linde's invention. In applying the principle of self-intensive refrigeration,—

i.e., by utilizing the cold produced by allowing compressed air to expand,—Professor Linde was the first one to liquefy gases like air without the use of other liquefied gases and on a large scale. He also devised an ingenious process for the fractional liquefaction of air by which the bulk of the commercial oxygen is now manufactured. Thus the life-work of this great engineer and inventor includes at least three achievements of the first magnitude: The invention of the almost universally used liquid ammonia ice machine; the construction of the first and most successful liquid air machine, and the devising of the process of making oxygen by its liquefaction from atmospheric air.

ORVILLE WRIGHT.

ORVILLE WRIGHT, honorary B.S. of Earlham College, Indiana, 1909, and honorary LL.D of Oberlin College, Ohio, 1910, was born August 19, 1871, at Dayton, Ohio, and received his education in the common schools and public high-school of that city continuing in attendance until his seventeenth year. Under the lead of his elder brother, Wilbur, four years his senior, he acquired mechanical experience and skill in a small machine shop established by the brothers in Dayton for the repair of bicycles, and from this beginning they gradually developed their ambition and purpose to solve the problem of mechanical flight.

The experiments of Otto Lilienthal in Germany with *aéroplanes* capable of sustaining a man in gliding flight, during several years previous to 1896, when he was killed in one of his trials; those of Percy Pilcher in England with similar devices during the succeeding years until he, too, met his death by accident in the course of his efforts in 1899, and those of Octave Chanute in this country, who had during that same period safely made over a thousand short flights with gliding planes, spurred the young mechanicians to take up the work and to endeavor to carry it to completion.

They began in 1900, and in their earliest experiments improved on the work of their predecessors by the addition of two vitally important features—that of a front horizontal rudder for steering the planes in a vertical direction, and that of means for balancing the machine during its flight by devices for flexing the outer ends of the supporting planes. These essentials were developed in the course of experiments carried on through three years on the undulating sand dunes near Kitty Hawk Lighthouse, on the North Carolina coast, and brought the inventors to a clear recognition of the fact that with an engine combining a relatively high power with low weight the *aéroplane*, as they had learned to make it, could be made to carry a man in flight.

By this time the gasoline engines for automobiles had been brought to a point of efficiency closely approaching what the Wrights needed for their purpose; quickly they applied themselves to its further perfection and to combining it with their machine. Constantly difficult, frequently disappointing, and always dangerous was the work to which the earnest inventors were devoting themselves, but at last, in December, 1903, they achieved their purpose, for on the 17th of that month four flights were made,

two guided by Wilbur and two by Orville Wright. The last of these flights, made with Wilbur at the helm, continued for 59 seconds and extended over 852 feet. More would have been done within the next few days, but shortly after the last landing a violent wind gust, sweeping over the bay, caught the aëroplane and wrecked it. But the way had been found. The work of the Wright brothers had shown the possibility of human beings flying through the air at will, and the realization of those possibilities has since followed, as a matter of course. In working towards that realization, men of many nations and in many climes had taken large and honorable parts, and not a few, like the elder of the Wright brothers, have paid for progress with their lives. There was yet, and still is, need for perfect safety in the working of the aëroplane, but this final requisite is also being worked for, and by none with more promise of achievement than by the surviving pioneer of aviation, Orville Wright.

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
June 3, 1914.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 3, 1914.

MR. GEORGE R. HENDERSON *in the Chair*.

The following report was presented for final action:

No. 2593.—Atwater Kent Ignition System. John Scott Legacy Medal and Premium. Recommendation adopted.

The following reports were presented for first reading:

No. 2597.—G. A. Wheeler's Escalator.

No. 2599.—Coöperation with Research Corporation. Advisory.
Adopted.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting, Board of Managers, June 10, 1914.)

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DR. ROGER F. BRUNEL, Department of Chemistry, Bryn Mawr College, Bryn Mawr, Pa.

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 MR. HORACE B. SMITH, 2121 Oak Street, Baltimore, Md.
 MR. ALAN WOOD, 3RD, Flat Rock, N. C.

LIBRARY NOTES.

Purchases.

- ALLEN, C. FRANK.—Railroad Curves and Earthwork. 1914.
 BAILEY, E. H. S., and CADY, H. P.—Laboratory Guide to the Study of Qualita-
 tive Analysis. 1914.
 BERNOULLI, JOHANN.—Die erste integralrechnung. 1914.
 BILLITER, JEAN.—Die electrolytische Alkalichloridzerlegung, mit festen katho-
 den Metallen. 1912.
 COOLEY, M. S.—Vacuum Cleaning Systems. 1913.
 FISH, J. C. L.—Earthwork Haul and Overhaul. 1913.
 FOWLER, CHAS. E.—Practical Treatise on Subaqueous Foundations. 1914.
 HÖNIGSCHMID, OTTO.—Karbide und Silizide. 1914.
 MARS, GEORG.—Die spezial Stähle; ihre Geschichte, Eigenschaften, Behand-
 lung und Herstellung. 1912.
 Mineral Industry; its Statistics, Technology and Trade. 1892-1912. 1914.
 Moody's Manual of Railroads and Corporation Securities. 15th annual. 1914.
 NEWTON, I., BERNOULLI, D., and D'ARCY, P.—Abhandlungen ueber jene Grund-
 sätze der Mechanik die Integrale der Differentialgleichungen liefern.
 PARTINGTON, J. R.—Higher Mathematics for Chemical Students. 1912.
 PICKELS, G. W., and WILEY, C. C.—Text-book on Railroad Surveying. 1914.
 RAYMOND, WILLIAM G.—Elements of Railroad Engineering. 1913.

- SMITH, E. F.—Chemistry in America; Chapters from the History of the Science in the United States. 1914.
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Gifts.

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- Baldwin Locomotive Works, Record No. 78. Philadelphia, 1914. (From the Company.)
- Bangor Public Library, Annual Report 1913. Bangor, Me., 1914. (From the Library.)
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- Busch-Sulzer Bros.—Diesel Engine Co., The Diesel Engine. St. Louis, Mo., 1913. (From the Company.)
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- Carnegie Endowment for International Peace, Publication No. 1, Some Roads Towards Peace. Washington, D. C., 1914. (From the Endowment.)
- College of Physicians, Transactions vol. 35. Philadelphia, 1913. (From the College.)
- Florida Railroad Commission, Seventeenth Annual Report. Tallahassee, Fla., 1914. (From the Commission.)
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- Indian Railway Conference Association, Proceedings of the Locomotive and Carriage Superintendents Committee, 1913. Punjab, India. (From the Association.)
- The Industrial Commission of Ohio, Report No. 1 of the Department of Investigation and Statistics. Columbus, Ohio, 1913. (From the Commission.)
- John Crerar Library, Nineteenth Annual Report, 1913. Chicago, 1914. (From the Library.)
- KENNELLY, A. E.—Chart Atlas of Complex Hyperbolic and Circular Functions. 1914. (From the Author.)
- Keystone Blue Print Paper Company, Catalogue and Price List, 1915. Philadelphia, 1914. (From the Company.)
- Lane Mill and Machinery Company, Catalogue No. 7. Los Angeles, 1914. (From the Company.)
- Louisiana State University, Catalogue 1914. Baton Rouge, La., 1914. (From the University.)

- New Hampshire Annual Reports, 1911-12, vols. 1-4. Journal of the House 1913, Laws 1913. (From the State Librarian.)
- New Zealand Geological Survey, Palæontological Bulletin No. 1. Wellington, N. Z., 1913. (From the Survey.)
- Norton Company, 1914 Refractory Catalogue. Worcester, Mass., 1914. (From the Company.)
- Pennsylvania Auditor General's Report 1913. Harrisburg, 1914. (From the State Librarian.)
- Pennsylvania Department of Mines, Report Part One, 1912, Highway Department Report 1911-13. Harrisburg, Pa., 1913. (From the State Librarian.)
- Pennsylvania State College, Bulletin No. 129. State College, 1914. (From the College.)
- The Philadelphia Maritime Exchange, Thirty-ninth Annual Report, 1914. Philadelphia, 1914. (From the Exchange.)
- Railroad Commission of Nevada, Sixth Annual Report. Carson City, Nev., 1914. (From the Commission.)
- The Royal Scottish Museum, Report for the years 1913-14. Edinburgh, 1914. (From the Museum.)
- Smithsonian Institution, Harriman Alaska Series, vol. 14, pts. 1 and 2, Starfishes. Washington, D. C., 1914. (From the Institution.)
- U. S. Coast and Geodetic Survey, Hypsometry. Fourth General Adjustment of the Precise Level Net in the United States and the Resulting Standard Elevations. Washington, D. C., 1914. (From the Survey.)
- U. S. Naval Observatory, Second Series, vol. viii, American Ephemeris and Nautical Almanac 1916. Washington, 1914. (From the Observatory.)
- University of Idaho, Catalogue 1913-1914. Moscow, Idaho, 1914. (From the University.)
- University of Michigan, Calendar 1913-1914. Ann Arbor, Mich., 1914. (From the University.)
- University of North Dakota, General Catalogue 1914-15. University, N. D., 1914. (From the University.)
- University of Pennsylvania Engineering Alumni Society. By-Laws, Annual Report and List of Members. Philadelphia, 1914. (From the University.)
- University of Rochester, Annual Catalogue 1913-14. Rochester, N. Y., 1914. (From the University.)
- University of Tennessee, Register 1913-14. Knoxville, Tenn., 1914. (From the University.)
- University of Wisconsin, Bulletin 212, March, 1914, and Circular 27th February, 1914. Madison, Wis. (From the University.)
- Viaggio del Dott. Elio Modigliani in Malesia, Riassunto Generale dei Risultati Zoologici. Genova, 1909. (From Dr. Elio Modigliani.)
- Waltham Water Department, 41st Annual Report. Waltham, Mass., 1914. (From the Department.)

BOOK NOTICES.

QUALITATIVE ANALYSIS by E. H. S. Bailey and H. P. Cady. Philadelphia, P. Blakiston's Son & Co. 280 pages, 13.5 x 20 cm. Price, \$1.25.

It is difficult to understand why anyone thinks it necessary to add another to the endless list of manuals available to the beginner in this subject. However, the present book is a good one. Its characteristic feature is the prominence given to ionization, to the concentration-law, and to the physico-chemical explanation in general. These matters are discussed in a brief and clearly-written introduction, and are referred to at every opportunity in the course of the work. In other respects the book differs from those already in the field mainly in minor points.

ROBERT H. BRADBURY.

DIE ELEKTROLYTISCHE ALKALICHLORIDZERLEGUNG, by Dr. Jean Billiter. Published by Wilhelm Knapp, Halle, Saale. Vol. II, 182 pages, 25 x 16 cm. Price, 9.60 marks.

The first volume, which was reviewed some time ago,¹ was devoted to an exhaustive survey of the very extensive patent literature. The present volume will be much more interesting to the average chemist. It contains a description, illustrated by diagrams and half-tones, of those processes of alkali chloride electrolysis which have achieved technical importance. Among the processes which receive attention are the Griesheim-Elektron, the Hargreaves-Bird, the Le Sueur, the Bell, and several others not quite so well known. The book should, of course, be in the library of every specialist in the subject. It also offers valuable information to electrochemists in general, and to teachers.

ROBERT H. BRADBURY.

KARBIDE AND SILIZIDE by Dr. Otto Hönigschmid. Published by Wilhelm Knapp, Halle, Saale. 263 pages, 25 x 16 cm. Price, 13.60 marks.

This book, like the one by Billiter just discussed belongs to the series of Monographien über angewandte Elektrochemie. However, there is very little applied chemistry about it. It is simply a straightforward scientific account of the carbides and silicides, without much reference to their application. To those who have read Moissan's fascinating book, "Le Four Electrique," a great deal of the material will be familiar. However, work has been active in this field since the publication of Moissan's book, and the present volume fills a noticeable gap in chemical literature. It will be of special interest to chemists and teachers who are concerned chiefly with the inorganic side of the science.

ROBERT H. BRADBURY.

¹ J.F.I., Vol. clxxv, p. 548.

INDUSTRIAL CHEMISTRY, by H. R. Benson. Published by the Macmillan Company, New York. 431 pages, 19 x 12 cm.

This is a very brief account of chemical technology, intended especially for the use of students in engineering. Occasionally the effort to achieve briefly betrays the author into a kind of schematic treatment, which would accomplish little with the beginner. This is notably the case in the attempt to describe the fixation of nitrogen (p. 56). Chapter X, on alloys, would have been improved by paying some attention to the physico-chemical aspects of the matter. The space expended on the elaborate classification of clays, pages 239-247, might have been more advantageously employed. The various formulas given for sederite on pages 190 and 191 should be corrected.

In the main the book is accurate and up to date, and it will probably benefit the students for whom it is intended. The brief technology that will hold, in English, the unique position occupied by Ost, in German, is yet to be written.

ROBERT H. BRADBURY.

PUBLICATIONS RECEIVED.

Baltische Ausstellung in Malmö 1914. Katalog der Sonderausstellung für Feuerungstechnik. 92 pages, illustrations, quarto. Leipzig, Otto Spämer.

Aus Theorie und Praxis des Riementriebes, mit besonderer Berücksichtigung der "Riementriebe Boesner" D. R. P. Ein Handbuch zum Gebrauch beim Entwerfen von Triebriemenanlagen für Maschinen-Ingenieure, Betriebsleiter, Fabrikanten und Studierende von Fritz Adolph Boesner. 75 pages, illustrations, plates, tables, quarto. Berlin, A. Seydel, 1914.

Conférences de Radiumbiologie, faites à l'Université de Gand en 1913 par MM. Jacques Danne et J. de Nobele. Ouvrage publié par la Société Belge de Radiologie. 214 pages, illustrations, 8vo. Bruxelles, L. Severeyns. Price, in paper, 6 francs.

Third Annual Mining Exhibition organized by the Chemical, Metallurgical and Mining Society of South Africa, Catalogue of Exhibits. 64 pages, 12mo. Johannesburg, 1914.

U. S. Bureau of Mines: Bulletin 57, Safety and Efficiency in Mine Tunneling, by David W. Brunton and John A. Davis. 271 pages, illustrations, plates. Bulletin 79, Abstracts of Current Decisions on Mines and Mining, March to December, 1913, by J. W. Thompson. 140 pages. Bulletin 82, International Conference of Mine-Experiment Stations, Pittsburgh, Pa., September 14-21, 1912. Compiled by George S. Rice. 99 pages. Technical Paper 35, Weathering of the Pittsburgh Coal Bed at the Experimental Mine near Bruceton, Pa., by Horace C. Porter and A. C. Fieldner. 35 pages, illustrations. Technical Paper 59, Fires in Lake Superior Iron Mines, by Edwin Higgins. 34 pages, illustrations. Technical Paper 62, Relative Effects of Carbon Monoxide on Small Animals, by George A. Burrell, Frank M. Seibert, and I. W. Robertson. 23 pages. Washington, Government Printing Office, 1914.

U. S. Department of Agriculture, Bureau of Biological Survey: North American Fauna, No. 36, Revision of the American Harvest Mice, by Arthur

H. Howell. 97 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1914.

Mésure de Constantes des Lignes Téléphoniques par M. Bela Gati: 6 pages, illustrations, 8vo. No place, no date.

Philadelphia Department of City Transit. A program for rapid transit development with universal free transfers resulting from conferences between the Director of the Department of City Transit and the Management of the Philadelphia Rapid Transit Company. Submitted to his Honor the Mayor and the Special Committee of City Councils appointed under resolution of January 15, 1914. 16 pages, 8vo. Philadelphia, May 27, 1914.

Philadelphia Department of City Transit. Financial Aspects of the Program for Rapid Transit Development with universal free transfers. Submitted for Consideration. Statement made by Director of the Department of City Transit. 7 pages, 8vo. Philadelphia, June 2, 1914.

Benzol as a Substitute for Gasoline. ANON. (*Amer. Mach.*, xl, No. 13, 552.)—Benzol has the following advantages and disadvantages as a substitute for gasoline for automobiles. Witnesses before the Petrol Committee of the British Royal Automobile Club show that benzol appears to give, on an average, 15 per cent. more mileage and greater pulling power; its disadvantages are: (1) a difficulty in starting in cold weather, (2) a more objectionable exhaust, and (3) sooting of the valves. Benzol may be worked at higher compression and consequent greater efficiency; its tendency to freeze at comparatively moderate temperatures can be overcome by mixing it with alcohol or gasoline.

Dissipating Fog by Wireless. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—The Chemin de Fer du Nord in France is experimenting on the use of wireless waves for clearing away fog. It is well known that electric waves act upon the water particles which make up fog, so as to turn them into vapor. Following this idea, it is claimed that as much as 600 feet can be cleared up in front of the electric wires which are emitting the waves, the fog being at least partially dissipated, and this will be of great value in practice, especially for railroads and vessels at sea which will have time to avoid each other in this case.

CURRENT TOPICS.

The "Dia" Enclosed Flame-arc Lamp. P. HÖGNER. (*Elektrotechn. Zeitschr.*, xxxiv, 970.)—This article discusses the chief precautions to be observed in a successful enclosed flame-arc lamp. An important point is that the area of globe through which the main flux of light emerges should be kept hot, so that there is little deposition of the materials formed. This is attained in the "Dia" lamp by the use of two globes having a small air-space between which acts as a jacket, maintaining the temperature. The fumes are carried away and deposited in the armature above the globe, and can be conveniently cleaned at intervals. The burning hours are said to be 55 with direct current and 120 with alternating. A mean lower hemispherical candle-power of from 1800 to 4100 can be obtained with direct current, the specific consumption being from 0.20 to 0.24 watt per hefner. With alternating current the efficiency is, naturally, somewhat less. The polar curve for this lamp is given. Vertical carbons are used. Tables and diagrams are given showing how the mean, maximum, and minimum candle-power can be calculated with lamps hung at a prescribed height and distance apart.

The Daylight Effect in Radio-Telegraphy. A. E. KENNELLY. (*Radio Engin. Inst. Proc.*, i, 3, 39.)—The conclusion is reached that the changes of intensity of signals near sunrise and sunset are explained by reflecting effects which may be expected at the boundary surface or "shadow wall" between darkness (*i.e.*, air of small conductivity) and illumination (*i.e.*, air of marked conductivity). The theory and recorded observations are found to be in reasonable agreement.

Preparation of Pure Vanadium and Titanium. M. BILLY. (*Comptes Rendus*, clviii, 578.)—Titanium and vanadium were prepared in a state of purity, suitable for physicochemical determinations, by reducing the vapor of the tetrachloride (made to boil in a current of hydrogen) by contact with sodium hydride, heated to 400° C. to 420° C. The hydride was contained in porcelain boats, lined with fused salt, and could be made *in situ* by enclosing the boats in an apparatus of soft glass. The reaction was accompanied by incandescence but was not violent. Titanium was obtained as a gray crystalline powder, which was purified by treatment with alcohol, 10 per cent. hydrochloric acid, and water. Vanadium was dried in a current of carbon dioxide. The method seems capable of general application.

French Manufacture of Transparent Quartz. J. GALLOIS. (*Bull. Soc. d'Encour.*, cxxi, 205.)—Till 1911 the French were dependent on the English and German imports, but now they manufacture their own silica ware, a factory at Laigneville producing fused quartz which allows the whole mercury spectrum down to 2302 Angström units to pass through a thickness of 3 mm. of the medium, a transparency to ultra-violet rays which permits of its application to the sterilization of liquids as well as to industrial illumination and the manufacture of chemical ware. A new-mercury-vapor lamp with a quartz illuminating tube is described. In the initial position the mercury fills the illuminating tube, but when the current is started a coil attracts an armature connected by a rod with the tube, and turns the latter about 40° on its axis, whereby, on account of the shape of the tube, the mercury is divided into two portions and an arc is formed across the interval. Quartz lamps are constructed to work under tensions of 220 to 500 volts to 6600 candle-power. The most powerful will illuminate an area of 5 acres.

The Protection to Human Life Obtained by Earthing a Network. S. RUPPEL. (*Elektrotechn. Zeitschr.*, xxxiv, 1221.)—This article deals with the resistance through which connection is to be made to earth to lessen the danger from contact with any conductor. The resistance of the soil itself is very variable, according to its composition and to the temperature; in frosty weather its resistance rises enormously. Gas pipes and water pipes make a good "earth," but for various reasons they should be regarded only as auxiliary. Plates buried in water-carrying strata are good, but the cost is heavy if the necessary depth is great; moreover, there is some uncertainty as to the possibility of the water-level sinking in dry weather, in which case the resistance may rise to 100 ohms. This method may be varied by sinking iron tubes or rods. If holes are bored to the level of the water, and the pipes are then driven in, this works well; but there are various things to contend with such as the difficulty of driving the pipes to a sufficient depth without any special tackle, and the possibility of dry weather, which can be avoided, according to Creighton, by impregnating the soil with some salt solution. Another plan is to bury near the surface a considerable length of iron strip or galvanized iron wire. Thus if a length of about 50 metres of galvanized hoop iron, 25 mm. by 2 mm., is buried 35 cm. below the surface, the resistance would probably be about 3 ohms; but the moisture and the nature of the soil are important factors. The best method of protecting the poles of an overhead transmission line is then considered and curves are given showing how the voltage is distributed over the surrounding ground; and the ground might be impregnated with a solution of some salt, but it is doubtful how long this would retain its efficiency. Copper generally lasts longer than iron in the soil, though sometimes it is the reverse. For short

earthing connections, where cost is a small matter, copper wire 8mm. in diameter has been found effective. For longer connections, galvanized hoop iron, 20 mm. by 3 mm., is recommended; or a galvanized iron wire, 8 mm. in diameter, may be used, although it has a smaller surface. Under average conditions, iron has been found to last well. The "surface" method, in which a considerable length of piping or strip iron is buried at a small depth below the surface, is generally cheaper and more effective than the old plan of burying an earthing plate at a depth where it is, presumably, always moist. If the resistance is to be about 5 or 6 ohms, it is sufficient to bury about 40 metres of hoop iron, which would cost about \$5; or three pipes, driven to a depth of 2.5 metres, would be equally effective. An earth-plate, about 1 metre square, would cost about twice as much to bury, unless the ground was unusually wet.

Portland Cement. A. HANENSCHILD. (*Tonind. Zeit.*, xxxviii, 477.)—Portland cement was divided into fractions of different degrees of fineness by first passing it through a sieve with 4900 meshes per square centimetre and then grading the finer portion in an air centrifuge, the material being fed through a hopper on to a distributing plate, on leaving which it was submitted to the action of a centrifugal air current, produced by a fan rotating at 2180 revolutions per minute. In this way considerable quantities of material were treated, the different fractions being collected in a series of concentric receptacles. The finest fraction contained the greater part of the sulphates present in the cement. The various fractions did not differ much in composition except in regard to the loss on ignition, which was greatest in the finest fraction and decreased progressively with the decrease of fineness. The time of setting was accelerated, the volume-weight decreased, and the volume-constancy increased with increasing fineness. The greatest strength was possessed by Portland cement grains, the dimensions of which were between 0.0363 and 0.0197 mm. The finest flour, less than 0.007 mm. in size, rapidly absorbed carbon dioxide and water, and was therefore not adapted to yield cement of the greatest strength.

Aluminum Foil. ANON. (*Brass World*, x, No. 5, 166.)—The manufacture of aluminum foil is a growing industry in southwestern Germany. The foil is used instead of tin-foil for wrapping candied fruits, etc., and has several advantages over tin. The process used is to paint sheets of pure aluminum with a solution of oil that is soluble in water, placing the sheets one upon another, or folding them, and then rolling them out to double their length. The sheets are again folded and the process is repeated until the desired thinness is obtained. The cylinders of the rolling mill are warmed with water to 45° C. (113° F.). The sheets are rolled cold and finally annealed in a vacuum retort and cooled gradually.

Casein. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—Consul W. H. Hunt, of St. Etienne, France, forwards an interesting report on some recent notable developments in the production and industrial uses of casein. Casein, the principal albuminoid matter of milk, is now obtained by electrolysis, according to the following recently invented process: In the middle of a large vat of skimmed milk, heated to 80° C., there is placed a porous vessel containing a 5 per cent. solution of sodium hydroxide; an iron cathode is plunged in the soda and a carbon anode in the milk. An electric current sets free the phosphoric acid contained in the milk, and the casein precipitates. As compared with the method of obtaining casein by the use of acids or rennet, the cost of this process is very low, the yield is greater, and the casein produced contains no foreign ingredients. Vegetable casein, now produced on a large scale from the soya bean, can be put to the same uses as animal casein. The principal use of casein is in the manufacture of galalith (milk-stone), used as a substitute for ivory, tortoise-shell, celluloid, etc. Penholders, frames, purses, phonograph discs, and a great variety of other articles are now made of galalith. It is also used as a chemical fertilizer. Several other casein products have recently been introduced.

Mercury-Vapor Lamp. BILLON-DAGUERRE. (*La Revue Elec.*, Dec. 19, 1913.)—A note on a water-cooled, mercury-vapor quartz-tube lamp with projecting mirrors. The lamp consumes 18 ampères at 70 volts, or about 1260 watts, and gives about 3000 candle-power. The principal feature of the lamp is that it produces practically "cold" light. For example, this light may fall for any length of time on celluloid, etc., without producing a heating effect on or deformation of the illuminated portion. This feature is especially advantageous for microscopy and for photography.

Preservation of Wood. A. J. WALLIS-TAYLER. (*J. Roy. Soc. Arts*, lxii, 286.)—Wood should be seasoned for at least 6 to 12 months before treatment. (1) *Kyanizing* consists in steeping timber in a 1 per cent. solution of mercury chloride for 7 to 11 days. (2) *Burnettizing* comprises preliminary steaming, followed by impregnation in a 2½ to 2 per cent. solution of zinc chloride under a pressure of 7 to 8 atmospheres. In the *zinc-tannin* or *Wellhouse* process, treatment in a partial vacuum follows the preliminary steaming, a small percentage of glue is added to the zinc chloride, and after impregnation for 2½ to 6 hours at 100 to 125 pounds pressure per square inch, the timber receives a final treatment with a 0.5 per cent. solution of tannin under the same pressure for two hours. (3) *Creosoting* usually involves steaming of the dried timber, heating under reduced pressure, and treatment with creosote oil under a pressure of 100 to 180 pounds per square inch. The amount of creosote absorbed by the timber varies from 7 to 20 pounds per

cubic foot, and the temperature of the treatment should be between 100° and 130° C. In the *Curtis-Isaacs* process, the timber and creosote are heated to above the boiling-point of the sap at ordinary pressure in a retort having vents open to the air; the vents are then closed and the creosote is forced into the wood under pressure. The *Rueping* process consists in forcing, first, compressed air at a pressure of 80 to 100 pounds per square inch into the pores of the wood, and then at a higher pressure creosote oil, without relieving the air pressure. In the *Lowry* process treatment with creosote oil at 77° to 82° C. under a pressure of 180 pounds per square inch is followed by draining and a rapid vacuum treatment. In the *zinc-creosote* or *Rutger* process an emulsion of $\frac{1}{2}$ pound of "dry zinc" and 1.5 to 4 pounds of creosote oil per cubic foot of timber is used; the emulsion being continuously agitated (*e.g.*, by a centrifugal pump). The *Hasselmann* process uses a solution containing copper, aluminum, and potassium sulphates, heated 118° to 126° C. under a pressure of 35 pounds per square inch. In the *creo-resinate* process (especially suitable for wood paving blocks) air at 121° C., under a pressure of about 100 pounds per square inch, is substituted for steam; the antiseptic agent consists of 50 parts of creosote oil, 48 of resin, and 2 of formaldehyde, and impregnation is followed by a treatment with lime water at 100° C. under 150 pounds pressure. The *Guissani* process uses a mixture of anthracene and pitch heated to 140° C., in which wood is submerged until it is free from moisture and sap, after which it is successively treated with cold, heavy tar oil, and cold zinc chloride solution. In the *saccharine solution* or *Powellizing* process, suitable for the treatment of green wood, a solution consisting mainly of sugar, with a small percentage of arsenic, is used. The *Vulcanizing* or *Haskinizing* process consists in roasting wood, which has been previously dried by steaming, to a temperature high enough to coagulate its dried albumins (71° to 94° C.), and to resolve some of the fibre and sap with the production of wood creosote. In addition to the use of definite antiseptics and of a large number of metallic salts for wood preservation, mineral oils, preferably mixed with asphaltum can be used to fill up the open wood cells, thus protecting the timber from the action of heat moisture, and air. By the zinc chloride process the life of wood is more than doubled; creosoted wood lasts 25 to 50 per cent. longer than wood treated with zinc chloride, but costs three or four times as much. The amount of preservative injected into one cubic foot of various classes of timber ranges from about 3 pounds of mercury chloride in the case of hard woods to about 6 pounds for moderately hard woods and 10 pounds for soft woods, the corresponding amounts of creosote oil being 3, 10, and 20 pounds respectively. The average costs of preserving timber with zinc chloride, creosote oil, and mercury chloride are approximately 2.5 cents, 10 cents, and 16 cents per cubic foot respectively.

Earthquake Construction. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—Earthquake construction has now reached a very practical stage in the seismic districts of Italy, where all new buildings are being erected under strict supervision with regard to their ability to resist earthquake shocks. Professor Omori, the Japanese authority, has estimated that 99.8 per cent. of the deaths in the great Messina earthquake of 1908 would have been prevented if the buildings had been properly constructed.

Increasing Motor Power. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—A somewhat original method is used by the Brown-Boveri Works to increase the amount of power which a given electric motor can be called upon to furnish; for instance, where a factory uses a motor rated at 500 horsepower this new method allows of getting considerably more out of it, say 700 or 800 horsepower. This often makes it unnecessary to put in new motors for the increase of a plant, hence a great saving. The method depends upon the fact that in the induction motor the power factor often has a low value, so that the motor does not furnish nearly so much power for its size as it would were the power factor of higher value or nearly unity. For rolling mill motors, where these are subject to severe strains and overloads at times, the motor must be very much larger than the average power would demand, hence it is an advantage to use a smaller motor for the same power. This is done by a small extra device in the shape of a one-horsepower motor, coupled to a rotating commutator, and this acts to change the value of the power factor and increase the output of, say, a large 1000-horsepower motor with which it is used. The small device is connected to the circuit of the large motor.

Adhesion and Alloying of Electrolytically Deposited Metals. M. SCHLÖTTER. (*Chem. Zeit.*, xxxviii, 289.)—The degree of adhesion is satisfactorily determined by Burgess's method, in which a copper disc is soldered to the surface of the deposit, the force required to detach the latter from the underlying metal being measured by a spring balance. Several factors influence the degree of adhesion, such as nature and hardness of the deposit and of the cathode metal; generally speaking, a soft metal adheres more firmly to rough surfaces than to smooth ones. The molecular attraction between cathode and electrolyte is increased by the addition of alcohol, which improves some deposits. Several metals occlude hydrogen during electrolysis, part of which is given off subsequently as gas, which accumulates under the deposit and decreases the degree of adhesion. In some cases the deposit alloys with the cathode, and the two cannot be separated. Zinc, when copper plated first becomes yellow; the thin coating of brass is subsequently covered with the deposit of copper.

Petroleum Prospects in the Union of South Africa. E. H. C. CRAIG. (*Board of Trade J.*, March 19, 1914.)—*Petroleum*.—There is little probability of any extensive oil-fields being found anywhere in the Union of South Africa. Favorable geological structure exists only in Cape Colony, and there only in a narrow strip at the southern edge of the Karroo. No petroleum prospecting has apparently been carried out in this district, but the conditions are not favorable for large productions. It is suggested that the area south of Aberdeen, near Jansenville, Saxony, and Klipplaat station should be examined. Though it is by no means certain that petroleum will be found, such a well, if successful would open up a wide area, and, if unsuccessful, would set at rest all hopes of striking oil in the Union. Certain areas in northeastern Natal, which were not inspected, may perhaps furnish favorable geological structures.

Natural Gas.—There are areas in the coal measures in the Transvaal and Natal where natural gas can be struck in fair quantity. Supplies of gas under sufficient pressure to supply distant towns are improbable, but possibly the gas may be used locally at a profit.

Oil Shales.—None of the shales examined, with the exception of that at Kikvorschfontein, are comparable with the best Scotch shales, but the laboratory tests prove that very fair quantities of shale oil can be produced. The seams are thin, as a rule, but might prove quite profitable in South Africa, on account of the great demand for and high price of oil. The Kilvorschfontein, Moorfontein, Waailhock, and Hlatimbe-Umkomaas areas are all worth consideration, especially the last area, which lies within 100 miles of Durban, and because it seems probable that shale deposits may be found near the projected railway to Himeville. Prospecting of the folded belt of the Karroo system for crude petroleum and natural gas is of less importance than the development of the shale industry. All the evidence leads to the belief that an oil-shale industry has good prospects of proving successful.

Dielectric Strength of Thin Insulating Materials. F. M. FARMER. (*Amer. Inst. Electr. Engin. Proc.*, xxxii, 2193.)—This considers the question as to the variations in results that may be expected if the dielectric strength of an insulating material is determined by different methods. It emphasizes the need for some standard method to be used for such determinations. The main point examined is the effect of the electrode area on the apparent dielectric strength, and he shows, by means of tests carried out on a larger number of dielectrics, such as varnished cambric, vulcanite, oil, air, etc., that the size of the electrodes has a marked effect on the results. The electrodes in all cases were two similar flat discs, ranging in diameter from 1/64 inch up to 15 inches. The method of making the tests is described, and the results in the various cases are shown in curves and in tables of figures. The general conclu-

sions are that the apparent dielectric strength of insulating materials in *thin* sheet form is materially higher with small than with large electrodes. This is probably true of solid, liquid, and gaseous dielectrics, though the variations differ widely. With paper and cloth, and with electrodes varying between the limits of size given above, the variations may amount to 50 per cent.; with oil, under the same conditions, the variation is more than 1000 per cent. The electrostatic stress is concentrated between sharp points, and failure of the dielectric soon takes place; but if the needle points are rounded off, so that the electrodes have an appreciable area, the puncture value becomes much higher than with large electrodes. This means that the testing of thin dielectric materials must be done on some specified plan, in so far as the area of the electrodes is concerned, if any comparison is to be made possible between various materials. Other variables, such as temperature, moisture of the atmosphere, and the rate of application of the testing voltage, also should be specified; but these latter points are not dealt with in the present paper.

Sicilian Sulphur Trade. ANON. (*Chem. Trade J.*, March 7, 1914.)—According to the official report of the Compulsory Sicilian Sulphur Combine for the seventh working year, from August 1, 1912, to July 31, 1913, the total production of sulphur in Sicily was 351,752 tons, against 366,457 tons in 1911-12 and 391,908 tons in 1910-11. The failure to reach the normal production of 400,000 tons is again attributed to the general conditions and to the closing in 1913 of seven mines, in addition to the 16 mines closed in 1912. The total sales during 1912-13, including sales for future delivery, amounted to 497,246 tons, against 603,255 tons in 1911-12 and 816,818 tons in 1910-11. The total exports declined from 447,638 tons in 1911-12, to 434,473 tons in 1912-13. The most striking decline in the exports is that to France, which has always imported the largest quantity, and which took 32,970 tons less than during the preceding year. This decline is believed to be due to the establishment of large refineries in that country by the Union Sulphur Company. The exports to Germany increased by 6222 tons, to Norway by 5278 tons, to Russia by 4520 tons, to Turkey by 4352 tons, and to Sweden by 3422 tons.

Fuel Oil Production. ANON. (*Amer. Mach.*, xl, No. 13, 560.)—The world's present production of fuel oils of all kinds is slightly below 55,000,000 tons, of which 47,250,000 are petroleum oils; this is about 5 per cent. of the world's present coal supply. The oil-bearing regions of the earth have been but imperfectly explored as yet, and areas known to be petroliferous still await development, though the older fields of the United States and of Southern Russia begin to show signs of exhaustion.

Plasticity and Allied Properties of Clays and Kaolins. P. ROHLAND. (*Silikat-Zeits.*, ii, 30.)—The author contends, in opposition to the views of Brown and Montgomery, that all clays lose their plasticity when heated to a temperature at which the combined water begins to be evolved, 590° to 620° C. Above about 950° C., when the combined water has been driven off, the amount of heat absorbed by clays corresponds with the contraction, which increases progressively with the temperature, well-defined contraction taking place only in the cases of substances of marked colloidal nature. The plasticity, however, is dependent not on the combined water, but on the free water, which develops the colloidal properties latent in air-dry clays. The contraction on drying of clays is also a function of their colloidal nature, and therefore of their plasticity, this contraction not occurring with crystalloids. In many cases the colloids of clays are of organic nature, but some clays which contain practically no organic matter owe their plasticity to the formation of the colloidal hydroxides of aluminum, silicon, or iron, when the clays come in contact with water. The well-known effects of caustic alkalis on the plasticity not only of clays but also of cements, trass, zeolites, and the like are due to the development of colloidal properties by hydroxyl ions, every substance of a plastic nature requiring a definite concentration of hydroxyl ions to produce the maximum proportion of colloidal constituents.

Ultra-Violet Rays as Aid to Digestion. ANON. (*Elect. World*, lxiii, 359.)—According to a cablegram to the *New York Times*, Prof. Daniel Bertholet, of Paris, claims to have reproduced artificially the processes of digestion on food substances by the action of the ultra-violet rays from a mercury-vapor lamp. The food was placed in a quartz container, and the reactions proceeded without the aid of the usual ferments.

Straw-board Pulp. B. HAAS. (*Papierfab.*, xii, 305.)—In the manufacture of the straw-board pulp, oat-straw is digested with 10 per cent., wheat-straw with 13 to 15 per cent. of lime; the capacity of the digesters ranges from 900 to 2000 kilos., but considerable differences occur among different mills in the quality of the lime, the manner of slaking, the composition and quantity of water, and the dryness and pressure of the steam. The industry is not under general scientific control, and the quality of the product varies considerably. In many cases too much lime is employed, and the pulp becomes "greasy" and drains very slowly, clogging up wires and felts. The lime should be slaked slowly and completely and used when freshly slaked. By adjusting the chaff-cutting machine, running in the liquor at the time of charging, and steaming gently at the same time, the capacity of a digester may be increased 10 per cent. The charged digester should be rotated for a short time without

steam, then the steam admitted with the release cock open to expel the air. Then admit full pressure (4 atmospheres) of steam with the digester rotating. Digestion may be continued for two and a half to three hours.

Making Tungsten Ductile. C. TRENZEN. (*Brit. Patent* 26,800 of 1912.)—Tungsten and other metals are rendered ductile by heating the amorphous metal, which must not contain any crystalline particles or oxide, to a temperature at which it turns crystalline, viz. 1000°C. to 1200°C. , and then applying strong hydraulic pressure, 12,000 kg. per square centimetre. The metal thus treated is also less liable to oxidation and may be rolled and drawn at high temperatures.

Output of Calcium Carbide. ANON. (*Amer. Mach.*, xl, No. 13, 548.)—According to a French authority, the world's output of calcium carbide in 1913 exceeded 350,000 metric tons. The autogenous welding of metals requires a large quantity, about 22,000 tons being consumed for this purpose in Germany, as compared with 28,000 tons for illuminating. The price for calcium carbide in Europe was maintained at about \$55 per ton. The production and price are regulated by a syndicate, which at the end of 1913 was renewed for another term. The production of calcium cyanamide in 1913 was over 150,000 tons. The Odda works in Sweden have a plant capable of making 90,000 tons per annum. All European makers separate the nitrogen from the atmosphere by the fractional distillation of liquid air. The production of calcium nitrate in Europe is between 100,000 and 120,000 metric tons.

Mercury-Vapor Rectifier. K. NORDEN. (*Electr. World*, lxiii, 163, from *Elek. Zeit.*, Dec. 25, 1913.)—An illustrated account of the development of the large capacity mercury-vapor rectifier of the General Electric Company of this country and of the Allgemeine Elektrizitäts Gesellschaft. The special feature of the latest design of the latter company is the arrangement of the anodes in such a way that no mercury can be deposited on them; which would interrupt the valve action and produce a short circuit between the electrodes. The anodes are mounted on special side arms outside the rectifier proper, and the side arms are curved so as to get the anodes entirely out of the path of the cathode flame. This construction also permits easy cooling of the anodes. Data are given on a 105-kilowatt, 300-ampère, 350-volt mercury-vapor rectifier. A test at 100-kilowatt load extending over four hours showed a practically constant efficiency of 90 per cent.

Spread of Gypsy Moth by the Wind. ANON. (*Sci. Amer.*, cx, No. 10, 195.)—Experiments conducted by the U. S. Bureau of Entomology prove that the newly-hatched caterpillars of the gypsy moth may be blown, under favorable conditions, a distance of six miles or more. Thus the wind is an important factor in the spread of this destructive pest.

Wireless Telephony from Berlin to Vienna. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—Wireless telephony continues to occupy experimenters in various parts of Europe, and, although we have no very remarkable progress to report within a recent date we can mention some promising experiments which are being conducted between Germany and Austria. The Nauen wireless station, owing to its high mast, is favorable to long-distance working, and telephoning was effected from this plant to the Technical Museum at Vienna, a distance over 300 miles. Owing to special apparatus of a new design, it was possible to hear newspaper articles which were read at Nauen.

The Sixty-Cycle Rotary Converters. B. G. LAMME. (*Elect. Jour.*, x, 1124.)—The early troubles are analyzed and the effect of recent improvement shown. These are: Higher peripheral speeds and greater pole spacing, larger bars and a greater number of them in the commutator and commutating poles, allowing still greater peripheral speed. All these points tend to increased efficiency. The consequent slight disadvantages are referred to, and the adverse effect of commutating poles on "hunting" is shown. The remedy is the use of dampers on the field pole-faces. Converters run much better with turbo-generators than with slow-speed sets, the tendency to "hunt" being reduced since the angular variation of the turbo-generator is negligible. Most recent converters are self-starting, and here again commutating poles cause troublesome sparking, which can be overcome by lifting all the brushes except two. For variable voltage the synchronous booster type appears to be the only practical method for 60 cycles. The regulating-pole type requires a very crowded design of field.



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MODERN RESEARCH IN THE METALLURGY OF
IRON.*

BY

ALLERTON S. CUSHMAN,

Director, The Institute of Industrial Research, Washington, D. C.
Member of the Institute.

OF all the seventy or eighty elements of which the materials of the universe, as revealed and proved by the spectroscope and chemical research, are found to be made, there is none so interesting to mankind as iron. With iron man has carved his destiny upon the face of the eternal ages. With sword, scimitar, spear and javelin, he began his conquering march. Later the plow-share and the pen appeared upon the stage of action and proclaimed themselves mightier than the sword. In the present strenuous day we are more than ever in a position to realize that iron is indeed the king of the material elements, with powers potential to guide and to lead the destinies of our race. Let us, then, review briefly the characteristics and capacities of this most wonderful protean element.

Familiarity breeds contempt, and those things which have been given us in abundance are treated with but scant respect. A heap of scrap-iron excites the contemptuous survey of the average man, whereas a small pile of gold behind an iron grating awakens an answering glitter in his eyes. But let us take pause for a

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moment. Considered from the standpoint of a metal and not for what it represents, gold is one of the most useless, albeit one of the most stable, of elements. Unattacked by nature through corrosion and oxidation, its comparative rarity, and perhaps its great beauty, constitute its principal claims as a metal. As a medium of exchange, gold is ever subject to fluctuating value as measured by the commodity or necessity it buys, and in earlier ages it has been subject to the fraud and to the debasement of those whose purposes it has been made to serve. In fact, although among the most permanent and stable of elements, gold has had little or no practical purpose in history except for personal adornment and as a medium of sentiment. Man could have gotten along without this precious metal and easily found a substitute for it. But how about iron? Let us briefly review what this metal has been the means of doing in the development of mankind, and, to keep true to our subject, what man's research in connection with this wonderful element has brought about.

It is related that when Richard II of England and Saladin, the great leader of the Moslem hosts, met in the early days where modern history begins, the champion of the west displayed a broadsword so strong that with it he was able to cleave a thick bar of iron. To this accomplishment the hero of the east replied by a stroke of a scimitar so keen that it sheared in twain a thick cushion stuffed with down. And so the extraordinary characteristics and possibilities of this metal have been played upon by man throughout the ages, from the most ancient to the most modern days. Both for strength and delicacy, what element designed by nature for the use of man has equalled iron?

But it is not in the tale of war or even of agriculture, art or letters, or even in its protean strength that this element has signalized its highest or its best use to mankind. From the delicacy of the hair spring of a lady's watch to the high-powered shaft and gun of a modern battleship, its range exhibits itself. From a cambric needle to a modern steel railroad rail is a far cry, but consider for a few moments what fields of research and endeavor have been opened up through the simple fundamental fact that soft iron is possessed of the power of exhibiting evanescent or temporary magnetism, while steel, the product of iron, conceals within itself the power of developing permanent or lasting magnetic properties. With a tiny, delicately balanced magnetic needle,

the early explorers opened up new worlds and continents; but it has been in the development of this magnetic property in the hands, first, of great scientists like Michael Faraday and, later, in those of the modern research student, that vastly greater worlds of scientific possibility have been explored and opened up to the lasting glory and benefit of the race. Every electrical instrument, every dynamo, motor, telephone or telegraph, including the modern wireless systems, depend entirely upon the properties of magnetism.

With its wonderful properties, therefore, and with its development growing apace, it is not astonishing that the element, iron, and its derivative, steel, should have been not only one of the earliest but one of the most persistent subjects of research.

The terms "iron" and "steel" are more or less vaguely differentiated, both by the layman and the professional metallurgist. Therefore, before proceeding further with our subject, it will be well if we understand, at least for the time being, just what we mean by these terms. There is a difference of opinion even among scientific men who have spent their lives in metallurgical research in regard to the exact definitions of the words "iron" and "steel." For our present purposes, however, let us take refuge in the common definitions as given in the dictionary, to which the layman of the world turns for information in regard to the meaning of the words which he employs. Webster's New Century Dictionary defines iron very simply as the most common and useful of the metals, and this same authority defines steel as refined iron combined with carbon. These definitions, which the writer accepts as true ones both from the standpoints of common usage and scientific interpretation, lead us naturally to the introduction of the subject under discussion in this paper, namely, modern research in the metallurgy of iron and steel. Before proceeding further into our subject, however, it is necessary to pause long enough to point out that research work can be classified very readily under separate headings. In ancient time research work into the capabilities of metallic iron was confined to the wonderful old smiths and artisans who produced, by the crudest means, examples of hardened steel whose qualities and character challenge the admiration of and, perhaps, even to some extent defy imitation by modern methods. All that the ancient artisan found out he usually kept to himself, or at

best he divulged his secrets only to his own apprentices and immediate disciples. With this form of research work we are not at present concerned. Modern scientific methods, however, can be considered under two main heads which I shall distinguish as plant and laboratory research. When Bessemer and his contemporaries, some fifty to sixty years ago, conceived the idea of refining iron on the large scale of operation by the pneumatic process—that is to say, by blowing air under pressure through a mass of molten metal—the experimental work could only be done upon the plant scale of investigation, with its attendant difficulties, enormous cost and danger. It has been, comparatively speaking, only within the last two decades that laboratory research in iron metallurgy has come to the assistance of the clumsier and more cumbersome method of plant scale investigation. It must at once become apparent that the most useful and the richest field is opened up where the laboratory investigator and the man who knows how to work enormous masses of metal at high temperatures join hands with a common purpose in view.

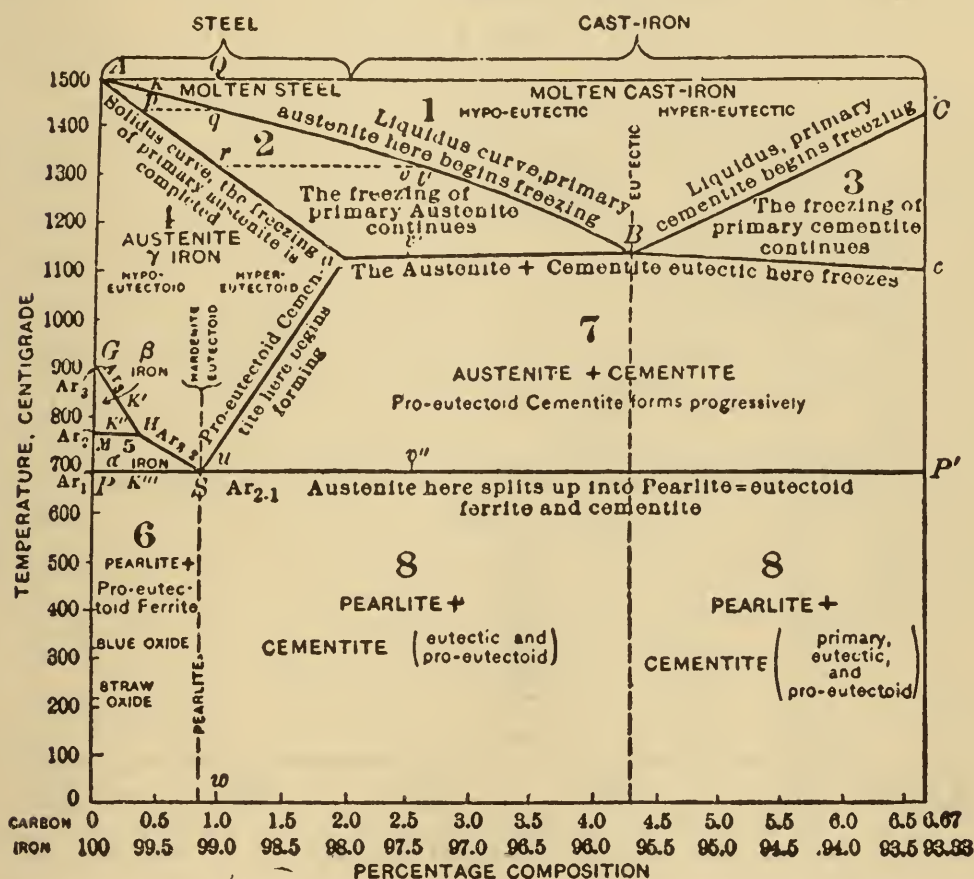
As has already been suggested, one of the extraordinary characteristics of iron depends upon the fact that it possesses an affinity for the element carbon, and combines with small quantities of this element in such a manner as to completely change its inherent characteristics. In other words, iron dissolves and seeks to dissolve in itself carbon, and it is this tendency which bears within itself potentialities of a most wonderful and extraordinary nature. I can best introduce this particular phase of the subject by making reference to what is known to metallurgists as the *Carbon-iron diagram*, which has been accurately worked out by research students and which as completely maps the possibilities lying within the combination of cast iron on the one hand and pure iron and high carbon steels on the other, as the geographical map is capable of placing before us a broad purview of the whole or a portion of the earth's surface. This diagram has been worked out with the aid of the microscope and by modern pyrometric methods for measuring high temperatures, even as high as those known to exist in the sun, with great accuracy, both lines of research representing to a great extent a very modern development.

The carbon-iron diagram, as worked out in its entirety by

our own distinguished metallurgist, Henry M. Howe, is shown in Fig. 1. For the sake of simplicity a detail of a portion of the diagram is shown in Fig. 2.

I cannot attempt, in the limited time allotted to me, to elucidate all that the iron-carbon diagram has opened up to us, but must content myself with pointing out some interesting and salient features.

FIG. 1.

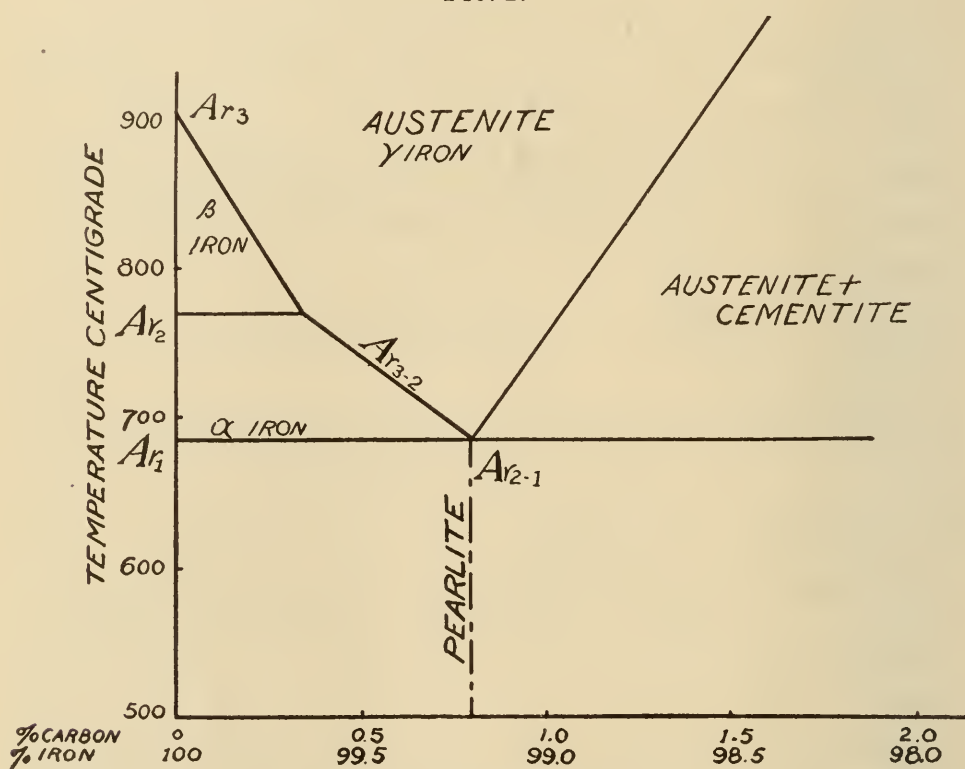


The carbon-iron diagram (Howe).

It has been known for a long time that if we heat iron or steel gradually until we arrive at the melting point of the metal, the rate of heating does not proceed uniformly. In the same way, if we start with iron or steel in the molten condition and cool it gradually, in both cases, at certain fixed temperatures, retardations in heat changes occur. These points are known as "critical points" or "critical temperatures." They are unquestionably caused by physical changes whereby heat is liberated at the critical

points on cooling, or absorbed on heating. The three principal critical points which have been mapped are designated as A_1 , A_2 and A_3 . On account of molecular inertia or lag, these changes occur at lower temperatures on cooling down than on heating up, unless the rates of heat changes are infinitely slow. To distinguish them, the cooling points are designated as AR_1 , AR_2 and AR_3 , while the heating points are written AC_1 , AC_2 and AC_3 . So decided are some of these extraordinary liberations of heat

FIG. 2.



Detail of iron-carbon diagram.

that the temperature of the cooling mass may be even raised slightly, and, when the observer is in the dark, a sudden glowing may be seen. This phenomenon is termed *recalcescence*, and has been made the subject of much research work and inquiry, a number of theories having been advanced to explain what takes place. The commonly accepted explanation is that iron exists in at least two, and possibly three, allotropic modifications, and that the heat which is given off or absorbed, as the case may be, represents the energy of atomic rearrangements which are taking place.

A very familiar example of an element which exists in several allotropic modifications, without changing its chemical constitution, is that of ordinary carbon. One allotropic form of this element is the diamond, while a piece of charcoal or a piece of graphite may represent two other allotropic modifications. In the same way, then, we are to understand that iron is capable of existing in different modifications, and that these interesting critical points are simply the temperature points at which these changes of form take place. According to the best authorities, as described by G. K. Burgess:¹

“The question of the allotropy of iron, in spite of a vast amount of experimental work and perhaps an even greater amount of theorizing, is not yet settled. That there is a definite transformation in iron near 900° , the A_3 point, is generally recognized, as well as the fact that the temperature of this transformation is lowered by the addition of carbon and metallic elements. On heating the transformation Ac_3 is always found at a higher temperature than the transformation Ar_3 on cooling. Whether the A_3 transformation is sharp, like the melting-point of a pure substance, or extends over a considerable range of temperatures, embracing perhaps as a lower limit the A_2 change, appears to be still an open question for pure iron. The nature and identity of the A_2 transformation, it would appear from recent publications, has not yet been satisfactorily settled.”

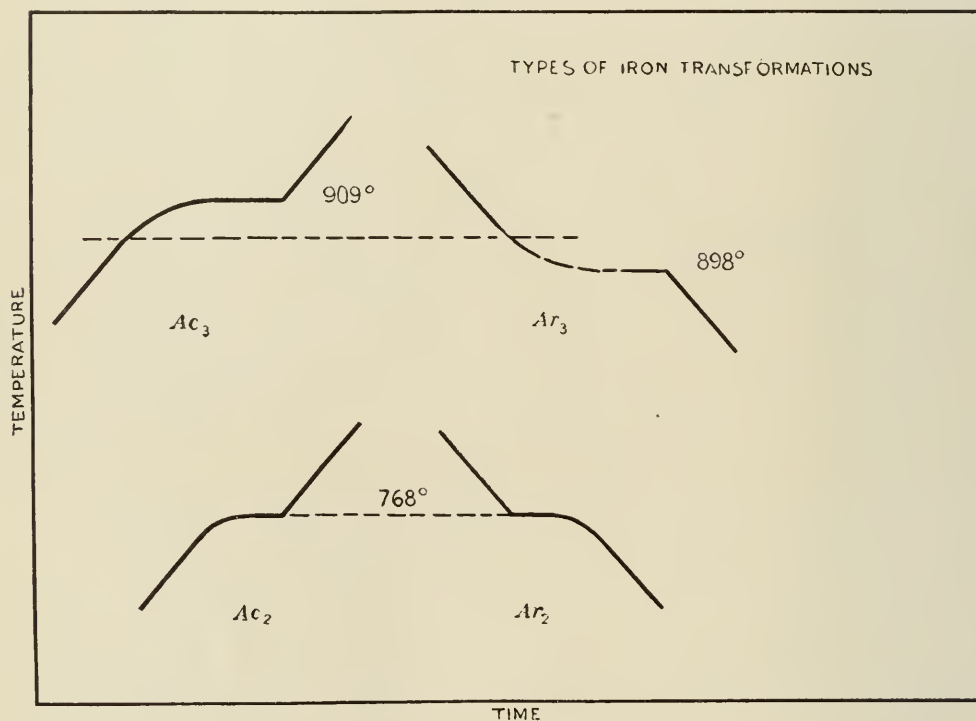
It seems at least to be generally conceded that the critical points A_3 and A_2 divide iron into separate allotropic forms. These are defined as α , β and γ iron. γ iron exists above A_3 and α iron below A_2 . The A_2 point may or may not be another transition point so that at the present time the existence of a β modification between A_2 and A_3 is in debate. The subject is too involved for discussion in this paper, but in any event it is certain that an interesting change or transformation takes place at the point A_2 which is associated mainly with the loss of the interesting property of magnetism which α iron exhibits. If chemically pure iron is the material under investigation, these critical points can be simply plotted on a diagrammatic curve, as published by G. K. Burgess and his co-workers and shown here in Fig. 3. When steels of varying composition are under consideration,

¹ Critical Ranges A_2 and A_3 of Pure Iron. G. K. Burgess and J. J. Crowe; Scientific Paper, U. S. Bureau of Standards 213, p. 316.

however, these critical points, as shown on the iron-carbon diagram, indicate all sorts of interesting changes which may take place.

That branch of metallurgy which treats of the constitution and structure of metals and alloys is known as metallography, and, with the aid of the microscope in the hands of research students, a number of different definite constituents of iron and steel have been distinguished, studied and named. Among these constituents it is necessary to define the following.

FIG. 3.



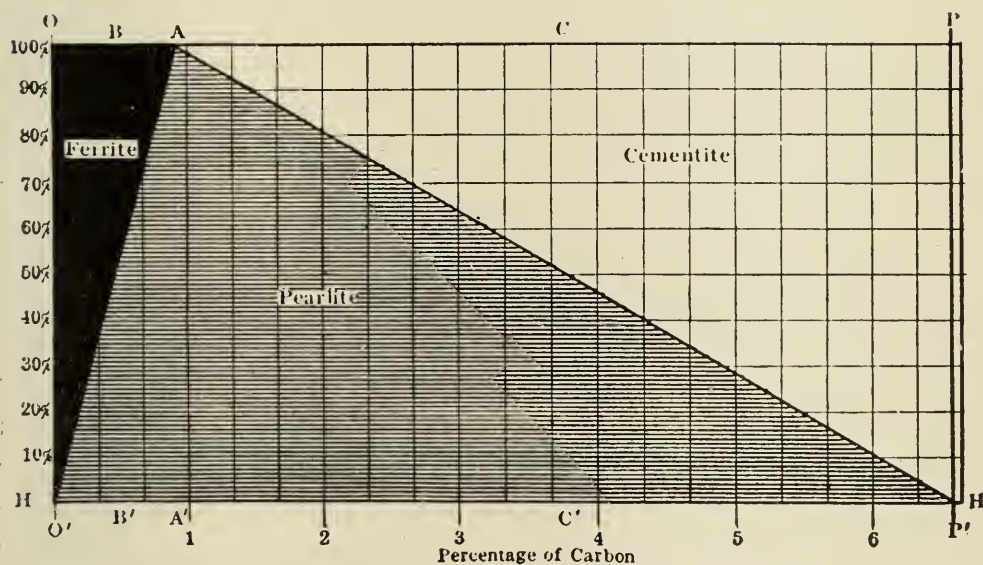
Ferrite is the name applied to pure iron, and is employed to designate that part of iron or steel which is not in combination with carbon but which may have crystallized out from a solidifying mass, in the practically pure condition. Ferrite is easily recognized under the microscope by its characteristic grain.

Cementite is the name given to a carbide of iron having a definite formula (Fe_3C). It represents a normal carbide of iron which also crystallizes out as a molten mass of carbon steel solidifies.

If a solution of common salt in water, such as sea water, is cooled at certain temperatures, depending upon the percentage of salt present, either salt or ice commences to crystallize out,

and this action continues until the remaining solution, called the "mother liquor," has a definite composition, when it finally freezes out together in a mixture of minute plates of alternate ice and salt which is scientifically known as cryo-hydrate. Whenever a similar action takes place in the cooling and freezing of molten alloys, the terms "mother metal" or "magma" and "eutectic" are substituted for mother liquor and cryo-hydrate, respectively. An interesting constituent which is always found in ordinary carbon steels which have been cooled in the usual way

FIG. 4.



Constituents of annealed carbon steels.

is a eutectoid or eutectic-like substance consisting of a mixture of alternate minute plates of ferrite and cementite crystallized out. When a sample of the solidified steel is highly polished and slightly etched with an acid body and examined under the microscope, this constituent appears as a pearly iridescent substance and is known to metallurgists by the appropriate name of *pearlite*. These separate substances, which we have defined as ferrite, cementite and pearlite, are the three most important constituents of steel which are ordinarily considered. The amount of pearlite, ferrite or cementite, in different compounds of iron and carbon, as shown graphically by O. M. Becker,² a well-known authority, is given in Fig. 4. The line of abscissæ here represents the amount of carbon present and the ordinates the amount of

² High Speed Steel; Becker. McGraw-Hill Book Co., New York, 1910, p. 26.

the three constituents. In addition to these constituents, however, the research student of iron and steel has to take into consideration a number of other important constituents which have been for the most part named after distinguished research metallurgists. Thus we have to consider such constituents as austenite, martensite, troostite, sorbite, and osmondite.

In a general way it may be explained that some or all of these carbon-iron constituents are formed when steel which has been heated to some temperature above the critical point A_3 , but below the melting-point, is suddenly quenched in water or oil and then perhaps slowly reheated or tempered. Such action is now known in a general way as "heat treatment." For instance, if a carbon steel containing about 1.5 per cent. of carbon is heated to 1100° C. and then suddenly plunged into cold water, a so-called solid solution of iron carbide (cementite) in pure iron (ferrite) is suddenly locked or fixed in the structure of the steel. This is the austenite of modern metallurgical research. If such a metal is subsequently annealed by prolonged heating, the austenite breaks down again into the softer pearlitic structure. This is an important point and should be borne in mind in order to make clear what we shall discuss later. Martensite is used to designate a transition from between austenite on the one hand and ferrite and cementite (pearlite) on the other, and is a varying combination of the three constituents. Troostite, sorbite, and osmondite we need not take time here to define in detail. In general, they are terms used to designate transition forms between the constituents already described. Pure iron, of course, consists only of ferrite and contains none of these various carbon constituents.

All this scientific nomenclature is of special interest to the immediate purpose of this paper only to the extent that it serves to illustrate what modern research has done and is now doing to explain and elucidate the extraordinary characteristics of iron and steel. The old-fashioned smith or artisan quenched and tempered his steels and was guided to his result by watching the characteristic colors imparted to his metal by the changes from one constituent to another. The modern metallurgist no longer trusts his eyes but is guided along his path of development by the aid of the microscope and pyrometer. As a distinguished authority has stated:³

³ Becker, *loc. cit.*, p. 7.

“ For at least a thousand years, and probably for several thousand, there had been no single important advance, no one striking development, in the nature and characteristics of steel, in respect to metal-cutting qualities at any rate. The property of becoming hard, possessed in common by all steels, and distinguishing them from ordinary iron, is due to the presence of carbon diffused throughout the mass of the metal. How the presence of the particles of carbon brings about the virtue of hardening is yet a matter of discussion.

“ Modern steel making is a fact only because the science of chemistry, itself scarcely a century and a half old, has made it possible to understand that there is an affinity of certain elements for certain others and that under given conditions exactly the same combinations can be expected in chemical compounds and alloys. The prehistoric steel makers had no idea that in firing iron with certain fuels they were carbonizing it, actually forming of the iron and fuel a new substance which contained besides iron the same element which in one form constitutes charcoal, in another graphite, and in a third diamond. That, however, is exactly what they did.”

The salient fact which makes research work in the field of iron and steel metallurgy so fascinating and valuable is the rich possibilities involved in its exploitation. The writer imagines, without knowing from personal experience, that the fascination of the pursuit of the study of music to a real musician or composer must reside in the almost infinite possibilities which lie within combinations of harmonies and musical themes. To a very considerable extent the modern metallurgist is a composer who is playing on a combination of almost limitless possibilities. If there is any one reason more than another which proves this statement true, it depends upon these two facts: First, because either by an accident of nature or by design the two elements, iron and carbon, possess affinities which cause them to combine in a succession of almost harmonic possibilities; and, second, because iron also has the power of linking up or combining with or dissolving in itself nearly all of the other material elements in such a manner and with such a character that the most minute quantities of these elements or combinations of them produce differences in the resulting metal or alloy, of the most profound and important nature. Allow me to dwell briefly on this idea.

It is an interesting fact that out of the seventy to eighty elements which comprise, as it were, the building blocks of the material universe, only about twelve or fourteen are commonly used either by nature or by man. All the others are what may be generally classed as rare elements, even the names of which sound strange and unfamiliar to the ears of men of ordinary education. These rare or rarer elements seem to comprise nature's scrap-heap, into which scientific man is painstakingly digging and delving in the effort to gain something from it for his purpose. What the chemist and physicist has done with this scrap-heap is prominently before us in these days, for he has discovered and introduced to us such wonder elements as radium and thorium, and now he is finding a use for the extraordinary element selenium, which changes its electrical conductivity under the influence of light and other sources of radiant energy. I would not like to prophesy as to the wonders man may accomplish in the future, due to this unusual and unique property possessed by the element selenium. But to return to our subject, I wish to point out that the research metallurgist has not been idle in poking about in nature's scrap-heap for elements to combine with iron and thus increase the wonder-working properties of this already wonderful metal.

Let us consider the names of some of the more prominent of these rare elements which research has introduced into the metallurgy of iron and steel, and review briefly what has been accomplished by their aid. Chromium, tungsten, vanadium, molybdenum, titanium, cobalt, tantalum—these rare elements have now their well-recognized place in the commercial exploitation of alloy steels. Steels containing, comparatively speaking, only very small quantities of these elements are made into tools which possess so-called self-hardening properties and are known as "high-speed" tools. With such tools as these, enormous chips can be cut at high speed in heavy lathe and machine work. In many cases the tools can be used without oil and the chip and tool can safely be allowed to run almost red hot without damage to tool or work. Think of the economies in labor and time introduced by such a wonderful property as this. How can the influence thus exerted by these rare elements be explained? Becker tells us: ⁴

⁴ O. M. Becker, *loc. cit.*, p. 6.

“ Carbon steel, as heretofore used in tools, no matter how well hardened, has not enough toughness and hardness to withstand the rubbing of the chip for any considerable length of time, even when not run fast enough to affect the temper. The tool therefore dulls; and this dulling proceeds in a sort of geometrical ratio as the cutting speed increases, being augmented by the drawing of the temper which accompanies rapid cutting. The speed in all metal-cutting operations has therefore had to be comparatively slow, no matter how powerful might be the machines in use. Thirty feet of chip per minute, as any machinist knows, has been considered rather good work; while fifty feet per minute has been very unusual. Under ordinary circumstances the management of a shop was pretty well satisfied if the machine tools could maintain an average speed of twenty to twenty-five feet per minute.

“ Such deliberation, necessary though it has been, is depressing in this era. A creeping mass of metal turning leisurely round and round or moving back and forth, as has been customary in the average shop, is quite out of harmony with the modern spirit of expedition and hurry. But while a few dreamed of the possibilities of cutting metal, some time in the future, with something of the vim with which wood can be cut; and while machines had been developed so tremendously as to leave scarcely anything to be desired in that respect; nevertheless the ultimate limit seemed to have been reached.

“ But it had not.”

In the review of the special constituents of steel, it was pointed out that certain extraordinary changes in the character of ordinary carbon steels take place, due to heat treatment through and about certain well defined critical points. The carbon-iron diagram shows that the hard constituents of steel are austenite and martensite, but if steels in which these constituents have been fixed by quenching and tempering are then annealed by high or prolonged heating, these constituents break down into the softer pearlite. Becker accounts for the influence of these rare elements as follows:⁵

“ Tungsten acts first as a strong obstruction to all the steps in the change from austenite to pearlite, so that if we have 7 per cent. or more of tungsten present, a moderately rapid cooling,

⁵ O. M. Becker, *loc. cit.*, p. 40.

even such as allowing the bar to cool in the air, will prevent the change to pearlite. Indeed, when tungsten steels are to be annealed and the pearlite stage produced, it is necessary that the cooling shall be very slow indeed, occupying several times as long as the annealing of normal carbon steels.

“Tungsten acts secondly as a powerful fixing agent for martensite. It has been already shown that martensite is not stable in normal carbon steel even after it has been induced there by hardening, unless the metal be kept cool. Warming it up to the so-called temper heats changes the martensite over to troostite,

FIG. 5.



The vanadium mines at Minas Ragra, near the backbone of the Andes.

and if the heating be continued, even the effective hardness of troostite is lost long before the steel reaches a red heat. The presence of 7 per cent. or more of tungsten, however, increases the stability of martensite so much that the steel may be heated well above the tempering heats before the martensite even begins to break down into troostite or pearlite.

“Red hardness is the quality of hardness when at a red heat, and tungsten imparts this to steel under certain conditions, for a time at least. That is to say, we may cut with a tungsten steel at

so rapid a rate that the point of a tool will reach that temperature where it almost begins to glow in a dark room, and still the steel will retain its hardness for many hours."

Vanadium, and vanadium and chromium together, are used to produce the wonderfully tough, anti-fatigue steels which are gradually supplanting all types of ordinary carbon steels in cases where very strenuous service is to be encountered, such, for instance, as in automobile and locomotive parts, and for springs of

FIG. 6.



The Meigs railroad leading up to the vanadium mines.

all sorts, which are more or less continually in motion. The extraordinary thing about vanadium is that less than two-tenths of one per cent. of this element is all that is usually necessary to confer upon steel this wonderful new property of resistance to fatigue. It is fortunate that this is so, for the principal source of vanadium is a vanadium sulphide ore which is painfully grubbed out of the sides and peaks of the Peruvian Andes, about sixteen thousand feet above the level of the sea. Fig. 5 shows the vanadium mines at Minas Ragra near the backbone of the Andes. Fig. 6 shows the Meigs railroad leading part way

up, constructed by Colonel Meigs, the well-known American engineer. The ore is carried in bags on the backs of llamas to the sea coast, and eventually landed in the Pittsburgh district, where it is made into ferro-vanadium, an alloy of iron and vanadium, which, in turn, is used by the alloy steel makers in the manufacture of their special compositions. It is a curious thought that this rare material is found only in these apparently inaccessible places and then is carried upon the backs of llamas (Fig. 7), representing the most primitive form of transportation used in commerce, to find its special service in the manufacture of the

FIG. 7.



A group of llamas ready to transport the vanadium ore from the mines to the railroad.

most finished and developed means of transportation such as the modern locomotive, automobile and aëroplane. Fig. 8 shows a vanadium steel saw which was kept coiled for four years and when unstrapped came out almost straight.

Titanium finds its special use as a deoxidizer or purifier of molten steel, and it has been claimed that its use in small quantities produces great improvement in steel rails. The use of any element which claims to safeguard life by reducing accidents due to rail breakage must be watched with interest. Cobalt is the latest recruit to be enlisted in the making of high-speed steels possessing especially valuable characteristics. As cobalt is a by-product of the Canadian silver mines, an abundant supply for this purpose is assured.

Our time does not permit us to dwell longer upon the wonderful achievements of research as applied to metallurgy in the field of these special alloy steels. It has been the special province of the writer to investigate that region of iron metallurgy which lies at the other extreme. Thus far we have been mainly discussing the influence upon iron of carbon alone or together with the rarer alloying metals. In the manufacture of ordinary steels, a certain group of elements is always present as impurities. Some of these impurities are desirable, while some are present only because it has until very recently been found practically impos-

FIG. 8.



Vanadium steel saw which was kept coiled for four years and when unstrapped came out almost straight.

sible to eliminate them on the large scale of operation made necessary by modern economic conditions. During the period of metallurgy which is comprised within the last century, men have been alive to the effects produced in iron and steel by the following elements which have often been referred to as the "big five." These are carbon, manganese, sulphur, phosphorus, and silicon. Owing to a peculiar condition of affairs that has arisen in the iron industry in America, we have now to add another common

element of impurity, namely copper, which changes the "big five" which the ordinary iron analyst is called upon to determine to the "big six."

In 1905 the writer, who was then engaged in the conduct of certain research work in the United States Department of Agriculture, was called upon to make an investigation of the alleged extremely rapid corrosion of steel fence wire and other forms of steel used in agriculture. After a careful study of all the available sources of information, and an extended research inquiry in the laboratory, evidence seemed to be pointing strongly in the direction that a great improvement in many forms of steel would be produced if the five ordinary impurities then considered could be reduced or possibly completely eliminated. As the result of the publication of these researches and those of other workers in the same field, the electrolytic theory of corrosion was developed and is now commonly accepted as the explanation of the underlying governing principles upon which the rusting of iron and steel depends. In spite of its wonderful and useful qualities, ordinary impure iron and its derivative steel have the weakness of being easily attacked, not only by the moisture and oxygen of the air, but by all forms of acid action. The sources and ores of iron are all found in the highly oxidized condition, and iron is only won from this combination by the expenditure of enormous quantities of energy. Once divorced from its combination with oxygen, it shows a tendency to again unite with this element and thus return to its stable condition. One of the interesting and important fields for research, therefore, has been the study of this tendency toward oxidation and to devise ways and means of overcoming and, to as great an extent as possible, circumventing it. The electrolytic explanation of corrosion teaches us that the presence of the ordinary impurities in iron tends to stimulate the action and to throw the corrosive attack particularly upon certain points or nodes of an exposed surface, thereby producing that most dangerous form of corrosion, which is known as pitting or tuberculation.

It has already been shown that when a solution of salt in water is cooled toward the freezing point, it does not congeal into a homogeneous mass of salty ice, but a certain selective action takes place, resulting in a separation of the resulting crystals, ice and salt. The same tendency exists when impure masses of

mother metal cool down to the solidifying point. Some constituents crystallize out before others and become segregated. Segregation is one of the important problems that the modern research metallurgist is called upon to study, for it presents dangers from many different points of view if it is allowed to take place in an uncontrolled manner. If an ingot is segregated, the finished product of the ingot will be segregated and is liable to breakage or to corrosion damage, according to the nature of the product or the kind of service it is designed to endure.

FIG. 9.



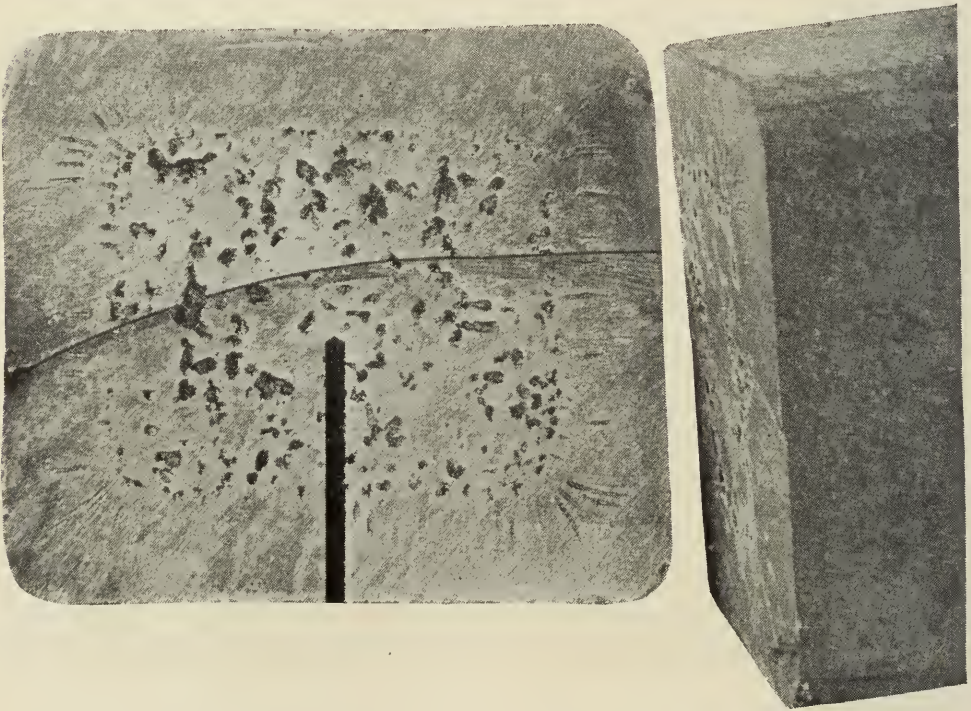
Longitudinal section, showing an open or spongy condition of a commercial steel ingot.

If segregation takes place as the metal cools and solidifies, the gases which are entrained or dissolved in the liquid bath cannot escape freely and therefore become entrained, producing an open or spongy ingot. Spongy ingots may be easier and less costly to bloom down than those which are solid and homogeneous, but there are, as the writer can testify, a number of honest and progressive manufacturers who are working to improve their ingots at the expense of very high cost in the maintenance of efficiently equipped research departments. It stands to reason that one way of overcoming segregation is to eliminate all alloying impurities, thus producing a pure

iron in which there is nothing dissolved which can possibly segregate. The solution of the problem of producing such a pure iron on the large scale of operation demanded under the conditions of modern social economics and modern industry has been no easy matter. It involved from the beginning the doing of what contemporary metallurgists and metallurgical text-books stated it was impossible or, even if possible, at best unwise to do.

The successful achievement of the results which are now obtained in the manufacture of pure iron on the large scale of

FIG. 10.



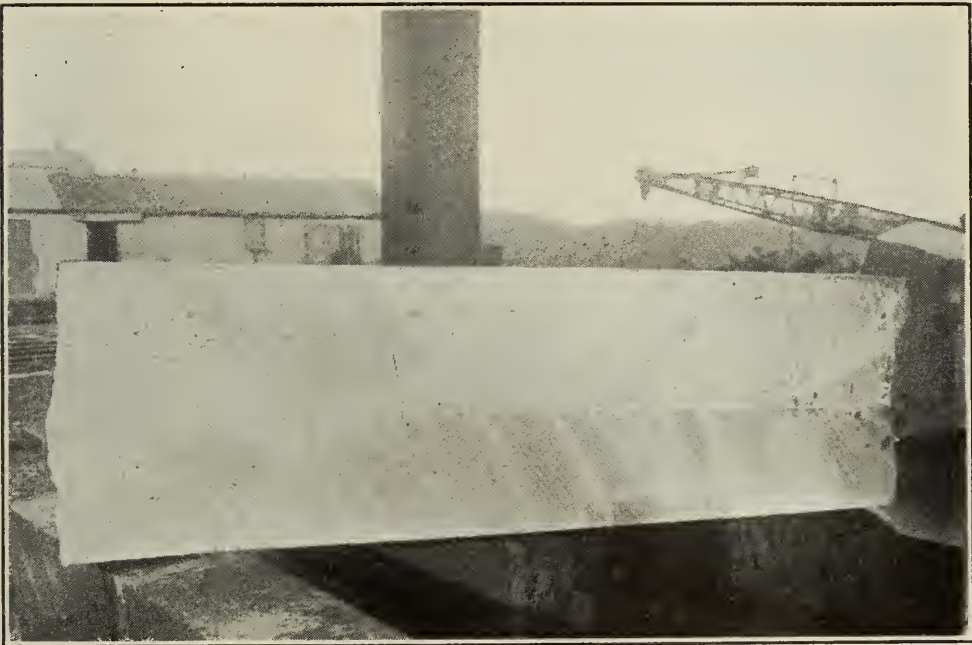
Cross section, showing an open or spongy condition of a commercial steel ingot.

open-hearth operation was not accomplished except as the result of very costly and strenuous research work in which determined men in the office, the mill and the research laboratory joined forces with a common purpose and with loyal energy. The writer is proud of the share he has had in this work and of the associations he has enjoyed with the group of men who have made it possible.

Where great strength is demanded, of course, pure iron is not suitable, but it has many interesting properties which differentiate it from ordinary steels or alloy steels. Pure iron is very soft

and malleable, and is capable of being most easily welded with the oxy-acetylene or oxy-hydrogen flame. A strip of this pure iron can be used as solder to join two ends or laps of the same material. It can easily be drawn into wire. Its electrical conductivity is 60 per cent. better than ordinary soft or mild steel. The comparative resistance of copper being taken as one, that of commercially pure, so-called ingot iron is 5.3, of charcoal iron 5.4, of Norway iron 5.8, of soft steel 8. For this reason, this pure iron can be and should be substituted for steel in the manufacture of third rails in the electrification of railways. Every saving in

FIG. II.



Longitudinal section of an ingot, showing improvement brought about as the result of careful research work.

the electrical resistance of the conductor is figurable into coal at the boiler end of the system.

In fact, this pure iron finds many interesting new fields of application, but its principal value so far has been due to its well known and well proven slow and even rusting quality. The writer has had comparative large scale exposure tests of various sorts and kinds under his observation for a number of years, and the pure iron seldom fails to give a good account of itself.

It has recently been claimed that ordinary steel alloyed with a little copper, say about .20 per cent., yields a metal of superior

rust-resistant properties, and is therefore as good if not better than the purest iron. D. A. Lyon, speaking recently before this Institute,⁶ voices this opinion in the following words:

“ . . . the writer believes that there is more evidence to warrant the belief that the presence of copper in proper amounts in steel does prevent corrosion, rather than that it does not, or, as some claim, by reason of its being an impurity, promotes it.”

I am one of those who do not agree with this opinion. It must be plain to every one that even if in some respects, notably in conferring an added resistance to an acid test,

FIG. 12.



A longitudinal section of a piped ingot, showing great density and freedom from blowholes in the body of the metal.

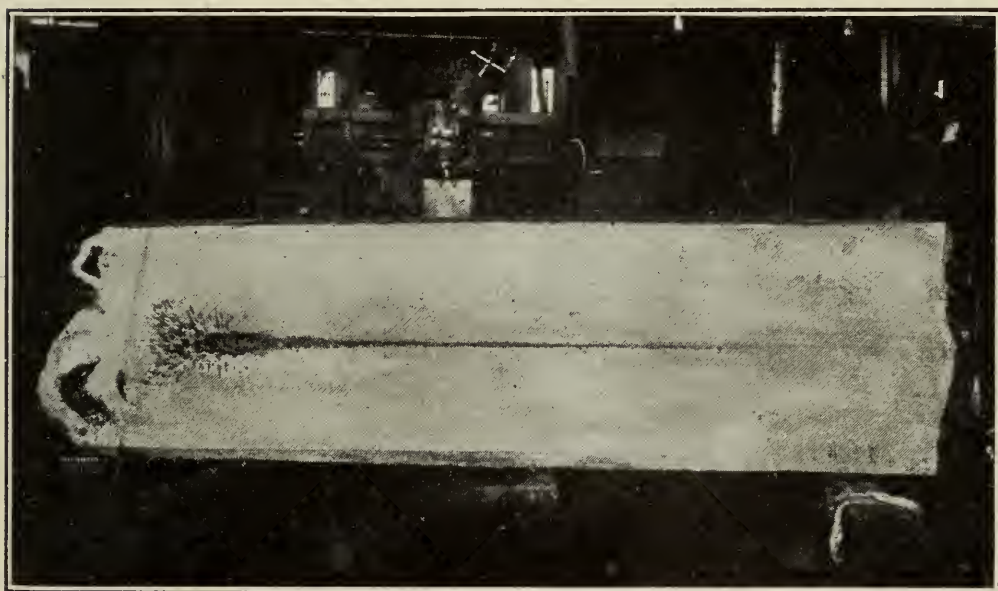
the presence of a small quantity of copper is held to improve the steel, its admission as a basis of specification introduces a grave danger. Copper need not be and generally is not purchased by the manufacturer for introduction into steel, as it is much simpler to employ a cheaper grade of scrap as a material of manufacture, which contains the copper in the form of machine wastes. It seems inevitable that behind the screen of coppered steel specification will lurk the cheap segregated metals that modern

⁶ JOURN. OF THE FRANKLIN INSTITUTE, Vol. CLXXVII, No. 2, 192.

research is trying so hard to work away from. Homogeneity and lack of segregation are the goal on which every progressive metallurgist has his eyes fixed, whether his special product is iron or steel.

Several recent lecturers before this Institute have discussed the bearing and importance of the production of sound ingots on the iron and steel problems of the day. You have heard of piped ingots on the one hand and of spongy, blow-holed ingots on the other. Between these two awkward extremes the con-

FIG. 13.

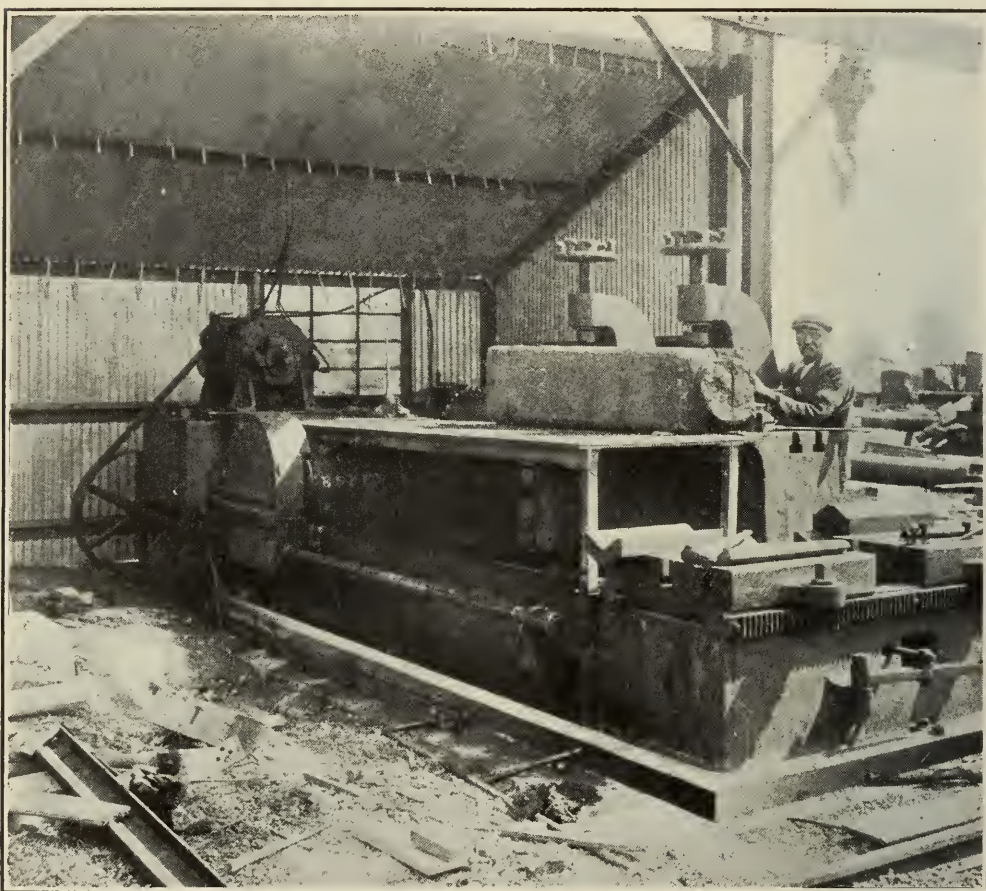


A longitudinal section of an experimental ingot, showing an extreme and dangerous form of piping.

scientious steel-maker is struggling as between Scylla and Charybdis. To a limited extent, the metallurgist has the making of sound ingots under control, but much remains yet to be learned in this respect. Five or six different methods or expedients for meeting this difficulty have recently been brought forward, but there is no record that any one of them has as yet proved its universal applicability. The difficulties attending this line of research are very great, as may readily be recognized. Modern ingots in big practice usually weigh at least 5000 lbs. and are 18" x 20" or more in cross-section and 5 or 6 feet long. If we vary our metallurgical practice, how are we to tell whether we have made any improvement? The only sure way is to saw a

number of selected ingots in two longitudinally, and thus open to inspection and study the centre of the mass. Such operation is difficult, slow and costly. Yet it can be done, and the writer is fortunate in having under his supervision an ingot-splitting saw so powerful that it will cut in two one of these huge masses in a few hours (Fig. 14). Directed by such instruments of research

FIG. 14.



An ingot-splitting saw at work. As the ingots measure 18" x 20" or more in cross section, this machine is very large and powerful.

as this, progress is rapid and great improvement in quality both as to strength and rust resistance of product is constantly being made.

The possession of this ingot-splitting saw has made it possible to study corrosion problems with special reference to the interior condition of the original ingot. After an ingot is split and has been studied, it is possible to roll down sheet metal into the full commercial sizes from the ingot and then put the sheets

out under atmospheric and certain accelerated tests. By this means it is possible to follow up the problem in a more intelligent manner than probably has ever been done before. In the illustration in Fig. 15 a general view of the atmospheric corrosion proving grounds under the supervision of the author is shown, and it includes many hundreds of full-size sheets of many types, manufactured from iron and steel ingots.

An interesting test which has been devised, which although

FIG. 15.



A view of the proving ground where full-sized commercial steel and iron sheets are tested by the author for corrosion resistance properties.

an accelerated test shows some very extraordinary results, is illustrated in Figs. 16 and 17. Large hollow-walled boxes are made of corrugated test sheets nailed side by side as panels, and the hollow walls are then filled with either cinders or manure. By this means it is possible to get results on resistance to corrosion, of experimental materials, in from six weeks to six months, whereas in ordinary atmospheric tests generally several years are necessary before decisive results can be obtained, upon which any definite conclusions can be built.

In spite of the extraordinary vigorous competition and differ-

ence of opinion in respect to the manufacture of corrosion resistant sheet metal, it is the desire of the writer to come at the truth of the matter through the methods of scientific research. A few years more of this sort of investigation work should furnish dependable data upon which to base conclusions. In the meantime, the various announcements made by special interests, in

FIG. 16.



A new form of corrosion test. Hollow wall boxes built up out of test sheets and then filled with cinders or manure to accelerate corrosion.

regard to corrosion resistance problems, should be accepted only in the spirit in which they are made—that of a desire to obtain the largest possible market for their own particular type of product.

Probably no field of metallurgical research is more interesting or more important than the development of special steels for use in the manufacture of high-power electrical machinery. We are facing, if we have not entered, the age in which electricity will be the great universal servant of man's evolution. The research metallurgist has been quick to respond to the call of the electrical engineer and designer for special types of iron and

steel to increase the efficiency and lower the costs of dynamos and transformers. Time will not permit me on this occasion to discuss the contribution of metallurgy to this most important line

FIG. 17.

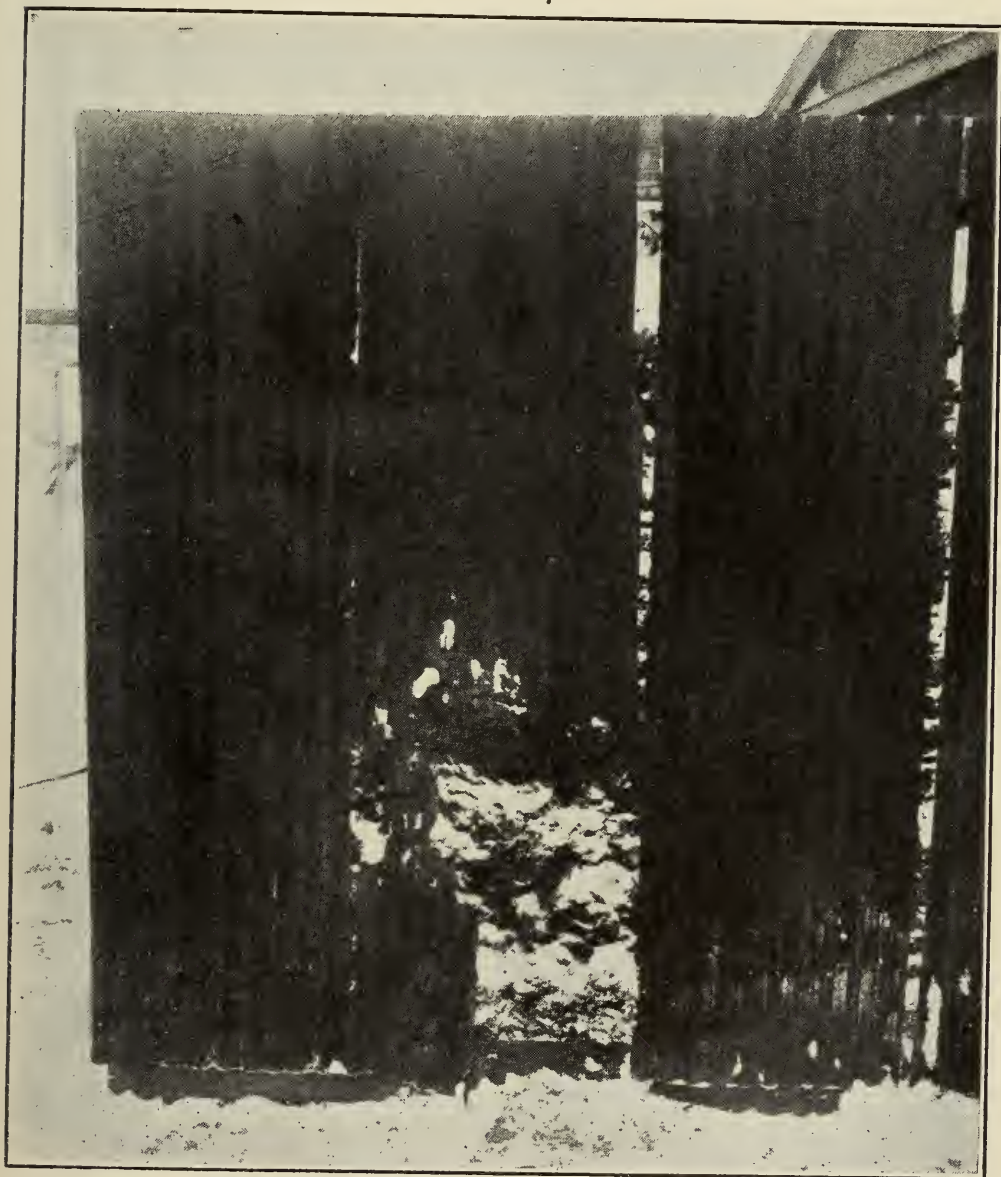


Illustration taken after 11 months' exposure in the box test, showing the failure of one type of sheet metal in competition with others. The gauge or thickness of the different panels is the same in each case.

of progress. There is material enough connected with the subject to call for a separate and special paper. It is interesting to note in passing, however, that it has been estimated, by a well-known electrical research engineer, that the metallurgical improvements

in transformer steels, brought about within the last few years by modern metallurgical research, represent a saving in money which would amount, if capitalized at 6 per cent., to approximately \$15,000,000 in the experience of one great manufacturing company alone. The writer knows that this claim is not exaggerated, and such statements stand for themselves when they are vouched for by those who are familiar with the data involved in making such calculations. No better argument than this could be advanced to justify the claim that modern scientific investigators are continually making, namely, that properly guided research work pays; that it is not a mere refinement or trimming on the edge of industry but, on the contrary, is a business asset which should be set down at or near the top of the column when the cost of high grade production is being computed.

One more thought and I am done. Research work is not alone the servant of the producer. Its results ramify in every direction. It does not seek to cheapen the materials with which the human race is carving its destiny, by degrading them in quality, but it does cheapen them by seeking to improve the methods of their production with due regard to the end and object they are designed to serve. Scientific research work in a nation, as Germany has demonstrated to the world, is a national asset which should be understood and encouraged by all the people. In this country we are only just beginning to realize the importance of development along this line. Something has been accomplished, but, in closing this paper, the deathbed words of a great man recur to my memory: "So little done! So much to do!"

Instrument for Solving Spherical Triangles. ANON. (*Eng. News*, lxxi, 180.)—Describes, with photographs, an instrument called the "mechanical navigator," which solves mechanically, by the setting-off of angles on rotating arcs, all the problems in spherical trigonometry which arise in navigation. By manipulating the instrument a navigator may find in one operation a ship's position at sea from two sights, making allowance for the ship's run. This is equivalent to solving three spherical triangles simultaneously, thus avoiding the use of the method of the Sumner lines, or their treatment by the method of Saint-Hilaire. The result thus found mechanically is claimed to be within 2' of arc, or less than the theoretical errors of the above methods. A detailed description is given of the method of use in certain cases.

PRODUCER GAS FROM LOW-GRADE FUELS.*

BY

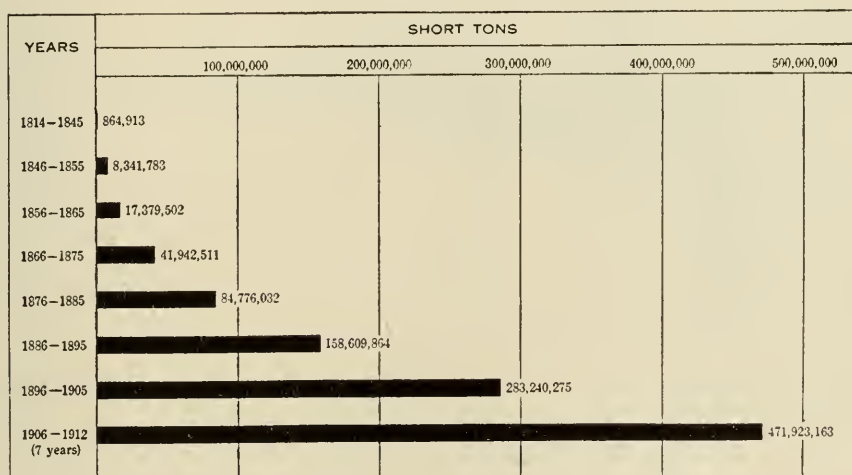
R. H. FERNALD, M.E., Ph.D.,

Consulting Engineer, U. S. Bureau of Mines; Whitney Professor of Dynamical Engineering,
University of Pennsylvania, Philadelphia, Pa.

Member of the Institute.

THE Reports of the U. S. Geological Survey show that, if the rate of increase of fuel consumption in this country that has held for the past fifty years is maintained, the supply of easily available coal will be exhausted before the middle of the next

FIG. 1.



century. As is shown in Fig. 1, the production of coal in the United States increased from less than twenty million tons fifty years ago to nearly five hundred million tons in 1912; if the industries of the country continue to develop at a sufficient pace to maintain this rate of increase, then the limit of our coal supply will be reached in about 200 years. As a matter of fact, the fuel consumption per capita is actually increasing much faster than the population, so that the question of the continuation of this rate of increase is one of considerable importance.

It is interesting to note that the production of coal in the United States has been for some years greater than that in any

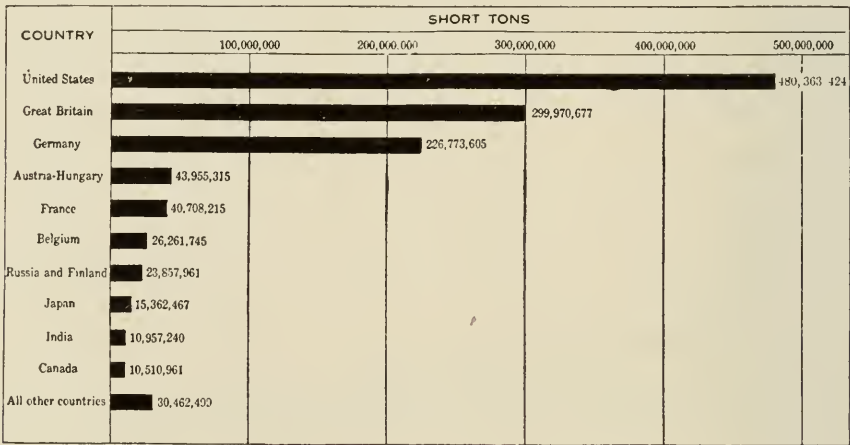
* Abstract of lecture delivered at the stated meeting of the Institute, November 19, 1913.

other country. The world's production of coal by countries for 1907—the last year for which figures are available to the writer—is given in Fig. 2.

The disposition of the coal fields in this country, as well as the relative areas of the different grades of coal, is indicated in Fig. 3. The limited supply of good coal makes it necessary to mine large quantities of sub-bituminous coal and lignite to meet future conditions. It will be noted that there is very little overlapping of the bituminous and lignite areas.

Most of the United States lignites do not weather well, but break down and crumble into fine dust when exposed to the atmosphere for any length of time. There are, however, extensive areas

FIG. 2.



of lignites in Alaska which stand up very well under weather conditions.

A great many low-grade bituminous coals and lignites may be utilized for power purposes by briquetting, and the use of this process industrially is gradually increasing. Briquetting, however, raises the price of the fuel by a considerable amount. It costs 90 cents to \$1 per ton to briquette coal, and this large expense is practically prohibitive in competition with cheap fuel. On account of the expense, it appears that briquetted coal will hardly become adopted for large plant work, though this form of fuel undoubtedly serves well under certain conditions for domestic purposes.

Another low-grade fuel is peat. There are large deposits of peat in this country, and in Canada there are some 37,000 square

miles of peat area from six to ten feet in thickness. Peat is prepared in Sweden, Denmark, Germany and Russia, and is also secured extensively in Ireland and some parts of Holland. The distribution of peat in the United States is shown in the map, Fig. 4.

When it comes from the bog, peat contains about 85 per cent. water, but when "commercially dried" by exposing it to the sun, it contains from 25 to 30 per cent. moisture. Commercially dry peat has a heat value of about 8000 B. T. U. per pound, and

FIG. 3.



▨ Anthracite & Bituminous, 250,531 sq.m. ▨ Sub-bituminous, 97,636 sq.m.
 ▨ Lignite, 148,609 sq.m.

is very suitable for use in gas producers, as very little or no steam need be introduced with it.

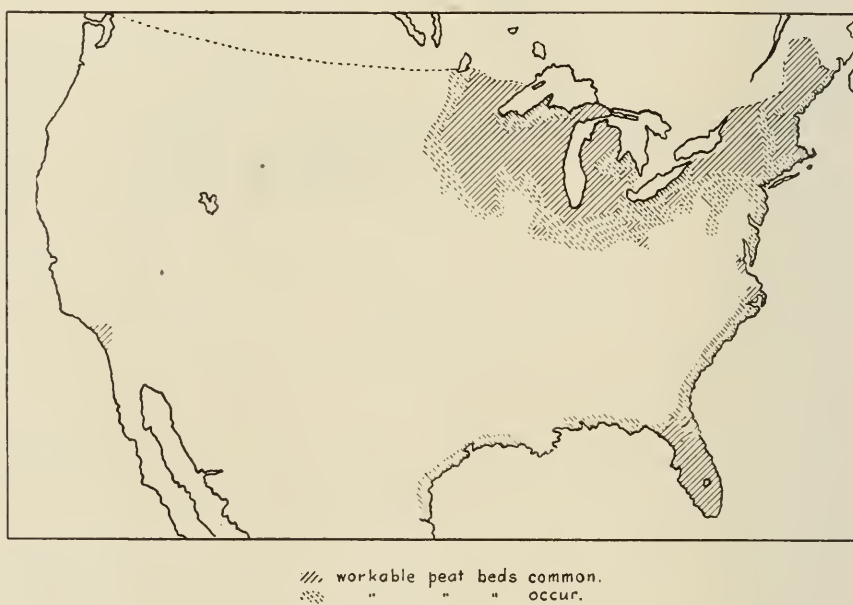
In view of the necessity of utilizing, for the production of power, grades and varieties of fuels which have not until recently been considered economical, the U. S. Bureau of Mines has conducted a number of investigations on the making of producer gas from such fuels.

The introduction of the gas producer into this country for power plant work was made about the year 1900. In that year the number of installations was very few—perhaps two or three plants—but since then it has steadily increased. The total number of plants in 1911, of which the writer has record, was 660, and of these a large proportion were double installations, which were

not counted separately. The number of gas producer power plants in the United States at the present time is probably in the neighborhood of 1000. The total horsepower of such plants in the United States in 1900 was 2000; this has increased year by year until in 1911 it was between 160,000 and 170,000, some 80,000 of which was obtained from bituminous coal, some 70,000 from anthracite fuel, and about 10,000 from lignite.

Of the total number of plants operating in 1912, 84.5 per cent. used anthracite coal and 10.7 per cent. bituminous coal, while lignite was used in 4.4 per cent. of the installations. The anthracite plants, however, represented only 47.8 per cent. of the

FIG. 4.



total horsepower developed, the bituminous plants 46.3 per cent., and the lignite plants 5.4 per cent., while wood and oil developed the remaining small percentage.

Summarized data relative to producer gas plants in the United States, March, 1912, are given in Fig. 5.

The anthracite plants are scattered all over the country, though several are congregated around New York and Philadelphia. The lignite plants are chiefly in Texas and Washington; there was a marked increase in 1912 in lignite plants in the former of these States. The largest total horsepower is produced in New York, and the next in Missouri.

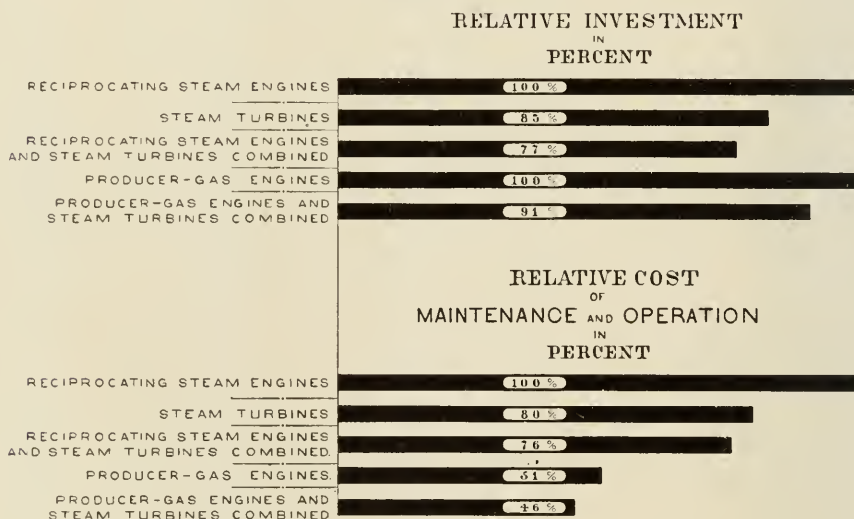
FIG. 5.
Summarized Data Relative to Producer-Gas Power Plants in the United States, March 1912.

	Horsepower												Percentage of total horsepower			
	Number of Plants			Total		Average		Minimum		Maximum		Percentage of total number				
	1909	1912	Percentage Increase	1909	1912	Percentage Increase	1909		1912		1909		1912		1909	1912
Anthracite coal: Over 500 H. P.	8	29	263	7,550	25,825	242	950	890	600	520	1,500	1,800	...	...	...	...
500 H. P. or less	407	581	43	40,550	63,645	57	100	110	15	15	500	500	...	...	...	...
	415	610	47	48,100	89,470	86	116	146	15	15	1,500	1,800	88	84.5	43	47.8
Bituminous coal: Over 500 H. P.	20	40	100	49,000	76,890	57	2,450	1,920	750	600	6,000	9,000	...	...	...	...
500 H. P. or less	17	37	118	5,150	9,725	89	300	262	35	25	500	500	...	...	...	...
	37	77	108	54,150	86,615	60	1,460	1,120	35	25	6,000	9,000	8	10.7	49	46.3
Lignite: Over 500 H. P.	3	3	0	7,275	7,275	0	2,430	2,430	525	525	3,750	3,750	...	...	...	...
500 H. P. or less	19	29	53	1,725	2,955	71	90	102	25	25	250	350	...	...	...	...
	22	32	45	9,000	10,230	14	410	320	25	25	3,750	3,750	4	4.4	8	5.4
Wood: Over 500 H. P.	0	0	...	0	0	...	...	...	...	...	...	...	...	...	...	...
500 H. P. or less	...	1	...	...	500	...	...	500	...	500	...	500	...	0.1	...	0.3
Oil: Over 500 H. P.	0	0	...	0	0	...	...	...	...	...	...	...	...	...	...	...
500 H. P. or less	...	2	...	...	325	...	...	163	...	100	...	225	...	0.3	...	0.2
Total	474	722	52	111,250	187,140	68	235	260	15	15	6,000	9,000	100	100	100	100

Factors which influence the installation of any particular type of plant are cost of installation and of maintenance, and economy. The average cost of producer gas installations is about equal to that of reciprocating steam engines; the cost of maintenance is, however, only about one-half, while the economy has been shown in several cases to be from two to three times as great. These statements are illustrated in Fig. 6.

At the Interboro Rapid Transit Company's Fifty-ninth Street Station, New York City, is one of the most efficient steam plants of which the writer has knowledge. At this plant 970 B. T. U. have to be put into the furnace to realize 100 B. T. U. at the

FIG. 6.



busbars. A theoretical gas plant devised on the same scale by Mr. Stott, Superintendent of Motive Power of the Interboro Rapid Transit Company, is shown in comparison in Fig. 7. In the gas plant 100 B. T. U. are obtained at the busbars when only 465 B. T. U. are charged into the producer.

Representing the figures in the above example in percentages, out of 100 per cent. of energy thrown into the furnace of the Interboro Rapid Transit Company's boilers, 10.3 per cent. is realized as useful work at the busbars. The theoretical gas plant assumed for comparison would deliver 21.5 per cent. to the busbars; this comparison is shown in Fig. 8.

At the Bureau of Mines Testing Station a 250 H. P. Corliss Engine, with 26.6 pounds water rate, with Heine Boilers, re-

quired 2060 B. T. U. charged into the furnace to secure 100 B. T. U. at the busbars, while a gas producer and gas engine, using the same fuel, required only 740 B. T. U. to deliver 100 B. T. U. at the busbars. In other words, 4.85 per cent. of the energy in the fuel charged into the furnace of the steam plant was delivered to the busbars, while 13.5 per cent. of that charged into the producer was delivered in the same way. These figures are shown graphically in Figs. 7 and 8 under "B. of M."

FIG. 7.

B.T.U.'s

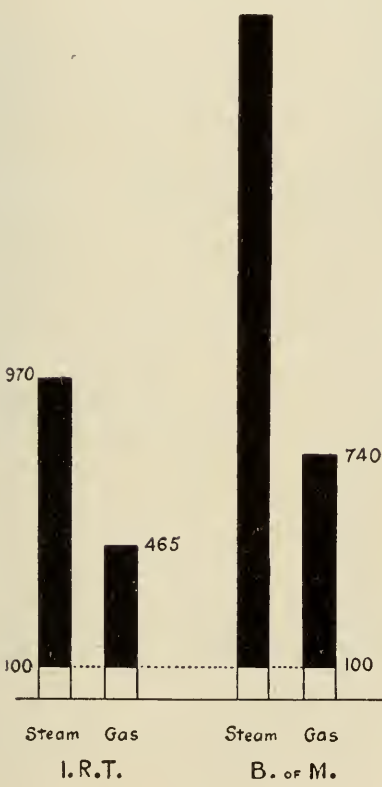
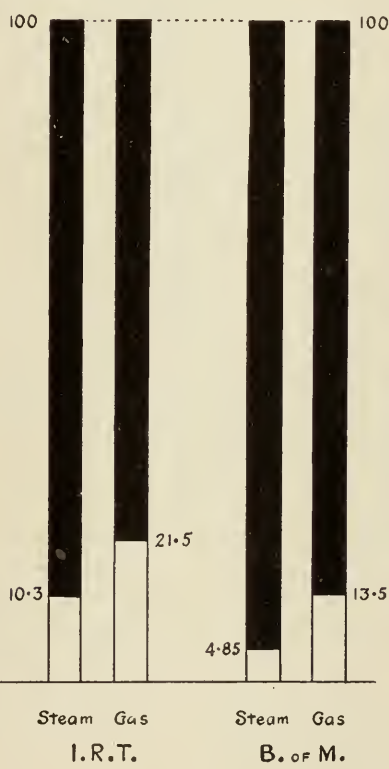


FIG. 8.

PER CENT

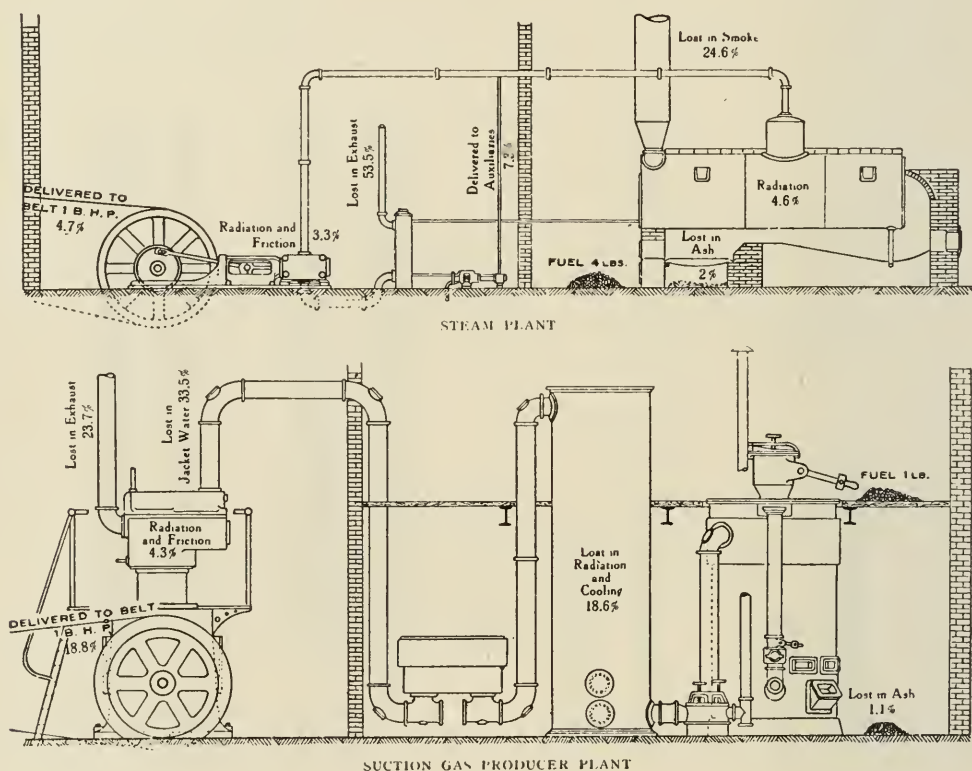


From a series of tests on a number of different Illinois coals, a comparison of the quantity of fuel per horsepower hour required in the steam plant and in the producer gas plant at the Bureau of Mines showed that, on the average, the former required 2.6 times as much as the latter. With fuel ranging in heat value from 14,000 to 15,000 B. T. U. per pound, the gas plant consumed approximately one pound, and the steam plant approximately three pounds per horsepower hour. Similarly, with fuels ranging between 7000 and 8000 B. T. U. per pound, the

gas plant consumed $2\frac{3}{4}$ pounds per horsepower hour while the steam plant required 7 pounds. These figures represent the average of a large series of tests of coals and lignites from different sections of the country. The following results were secured under similar conditions at each of these plants.

2.9 pounds of West Virginia run of mine coal containing 2.4 per cent. moisture per brake horsepower per hour were required

FIG. 9.



in the steam plant, while the gas plant required but 0.85 pound of the same coal.

With New Mexican run of mine coal, containing 19.6 per cent. ash, the gas plant required 1.1 pounds per brake horsepower hour, or just a little more than of the highest grade West Virginia coal, and very much less than the steam plant with West Virginia coal.

With West Virginia bone coal containing 44 per cent. ash which came in such form that a great deal of it resembled rock and, when struck with a hammer, threw out sparks, only 1.66 pounds per horsepower hour were required.

Many such fuels as the above can be utilized in producer gas plants, which require, as indicated, much less coal per horsepower hour than the corresponding steam plant.

Lignites usually run high in moisture, but make a gas of excellent quality. Less lignite was required per horsepower hour in the gas plant than of West Virginia coal in the steam plant.

Fig. 9 shows the distribution of heat in typical steam and gas plants. The heat losses in the two plants are as follows:

STEAM PLANT.

	Per cent.
Heat lost in ashes	2.00
Heat lost in radiation and cooling	4.60
Heat lost in smoke	24.60
Total losses in boiler	31.20
<hr/>	
Heat lost in radiation and friction	3.30
Heat lost in exhaust	53.50
Heat lost in jacket water	
Heat lost in auxiliaries	7.30
<hr/>	
Total heat losses in entire plant	95.30
Net efficiency of plant	4.70

GAS PLANT.

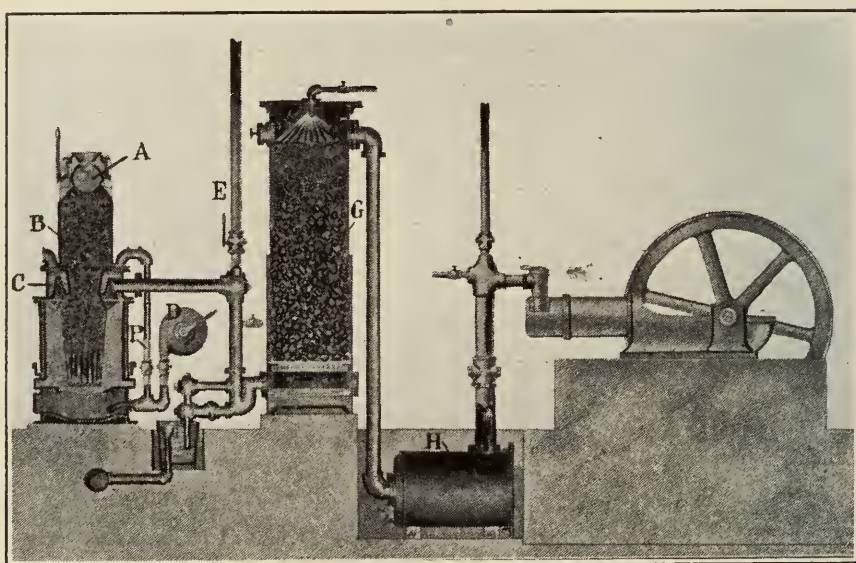
	Per cent.
Heat lost in ashes	1.10
Heat lost in radiation and cooling	18.60
Heat lost in smoke	
Total losses in producer	19.70
<hr/>	
Heat lost in radiation and friction	4.30
Heat lost in exhaust	23.70
Heat lost in jacket water	33.50
Heat lost in auxiliaries	
<hr/>	
Total heat losses in entire plant	81.30
Net efficiency of plant	18.80

Original heat in the coal in both plants = 13,500 units per pound.

There are several types of gas producers now in use, among which are the suction type, the up-draft pressure type, the down-draft type and the double-zone type.

The suction producer is the simplest in form. A typical suction producer is shown in Fig. 10. The operation is as follows: The producer *B* is fed with fuel from the hopper *A*, which is provided with some feeding device so that the fuel may be dropped into the container below without admitting air. *C* is the vaporizer for vaporizing the water and mixing it with the air. The steam-saturated air passes down through the pipe *P* to the bottom of the producer. *D* is the starting fan. The hot gas leaving the producer enters a vertical pipe *E*, the upper part of which can be opened to the air to allow the poorer gas to escape when starting.

FIG. 10.



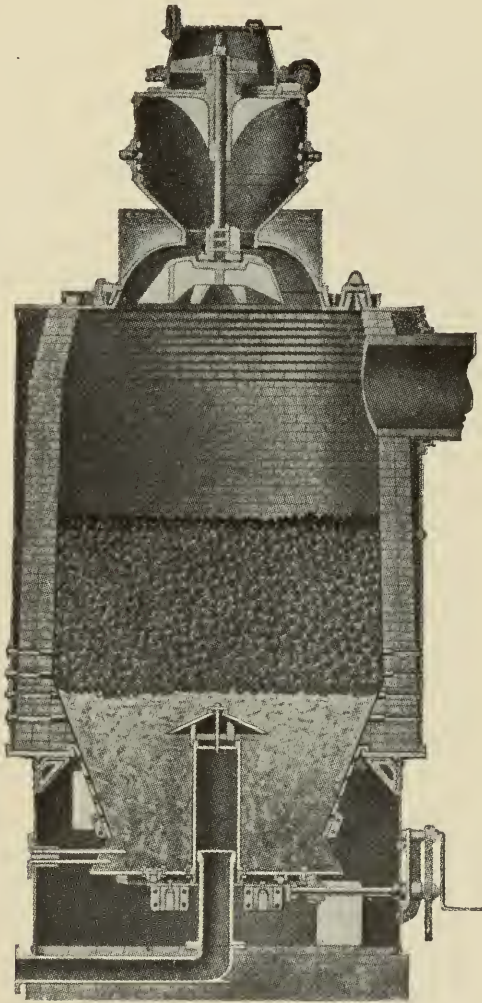
The gas passes down the vertical pipe through a water seal to the coke scrubber *G*. Tar collects at the bottom of *E* and runs into the tank shown. From the scrubber, the gas passes into the expansion box *H*, from which it is drawn by the piston of the engine into the cylinder.

The gas produced by the use of air and carbon only has certain excellent qualities for power purposes, but is rather low in heat value, and further than that, in making such gas there is a tendency for the temperature to rise to such a point that excessive clinkering is produced and fuel troubles are caused. The introduction of water or steam maintains the temperature at a sufficiently low point to prevent clinker formations.

When producer gas is made from coal, its constituents are carbon monoxide, a limited percentage of hydrogen and a small amount of marsh gas. Carbon monoxide is the main constituent.

Some gas producers embodying special features are shown in Figs. 11 and 12. The producer illustrated in Fig. 11 has a re-

FIG 11.

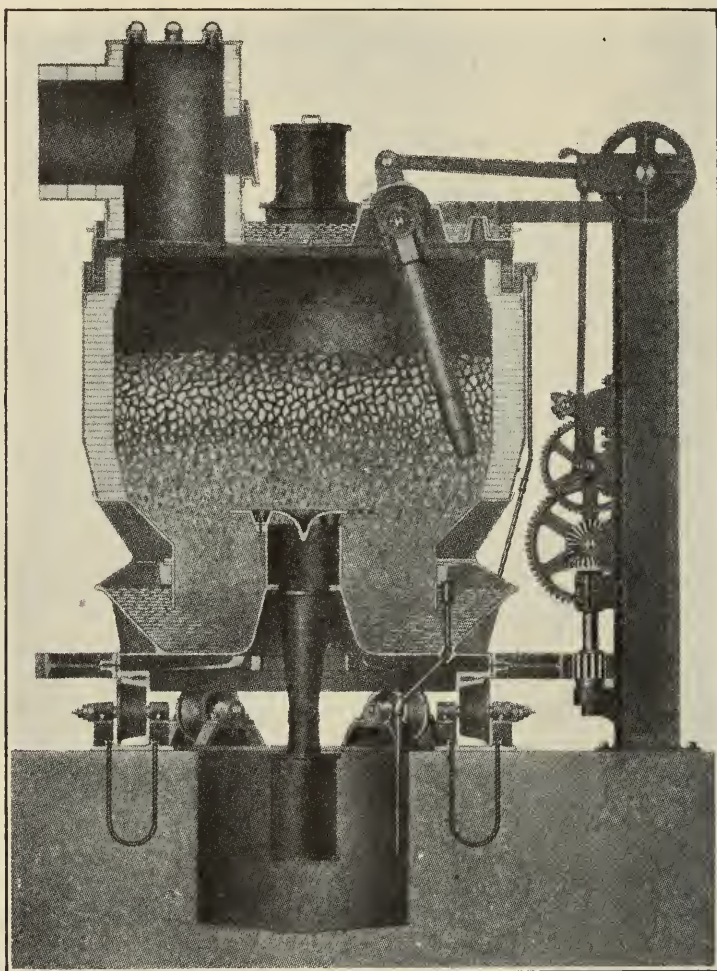


volving grate and an automatic feed. That shown in Fig. 12 is a mechanically-poked continuous gas producer.

A number of gas plants are provided with centrifugal tar extractors, for removing tar. Getting rid of this tar after it is removed is a very serious problem, and many attempts are being made to effect an increased utilization of this product commercially. Fig. 13 shows a system in which arrangement is made for converting the tar into gas available for use in the engine.

The method is to run two generators on a certain grade of fuel. The bed is a layer of coke; the fire is built on top of this and green coal is charged in over the fire. By this means an incandescent bed is formed. The draft produced by the exhaustor draws the gas downward from the green coal through the incandescent bed, and the tarry compounds are supposedly converted

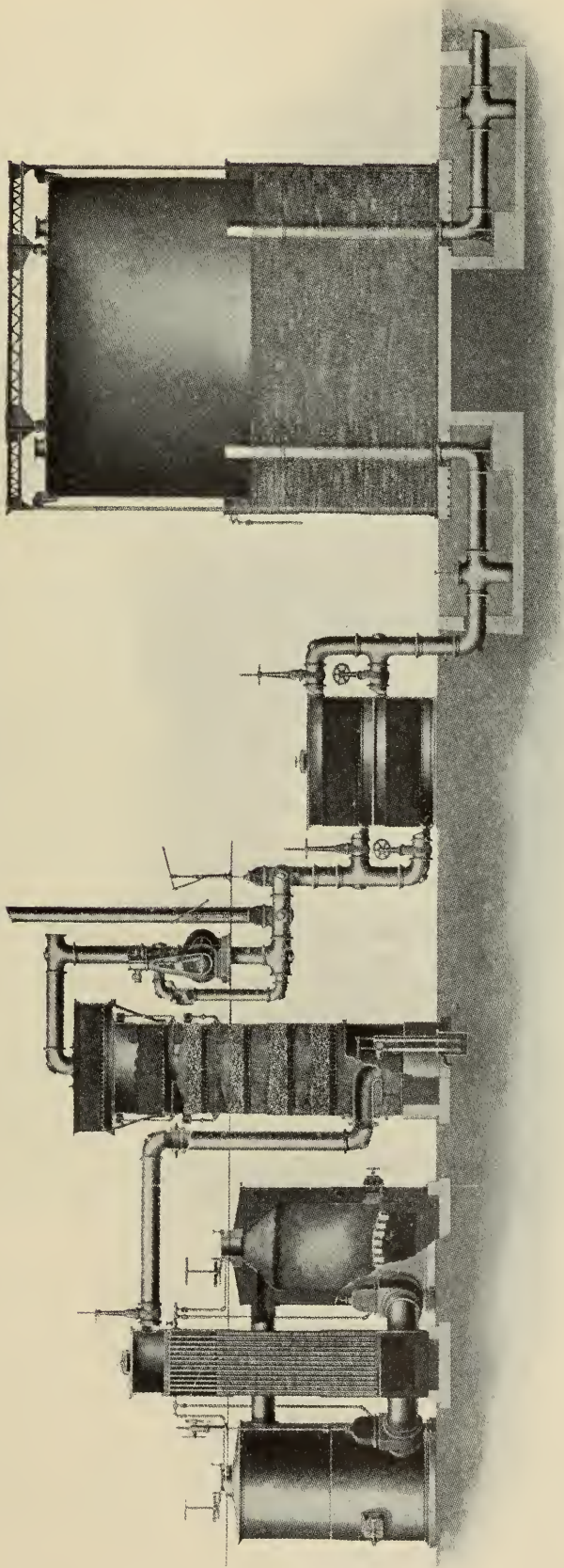
FIG. 12.



into gas. The products are then drawn through the wet and dry scrubbers to the holder. As shown in the figure, the exhaustor is situated between the wet and dry scrubbers.

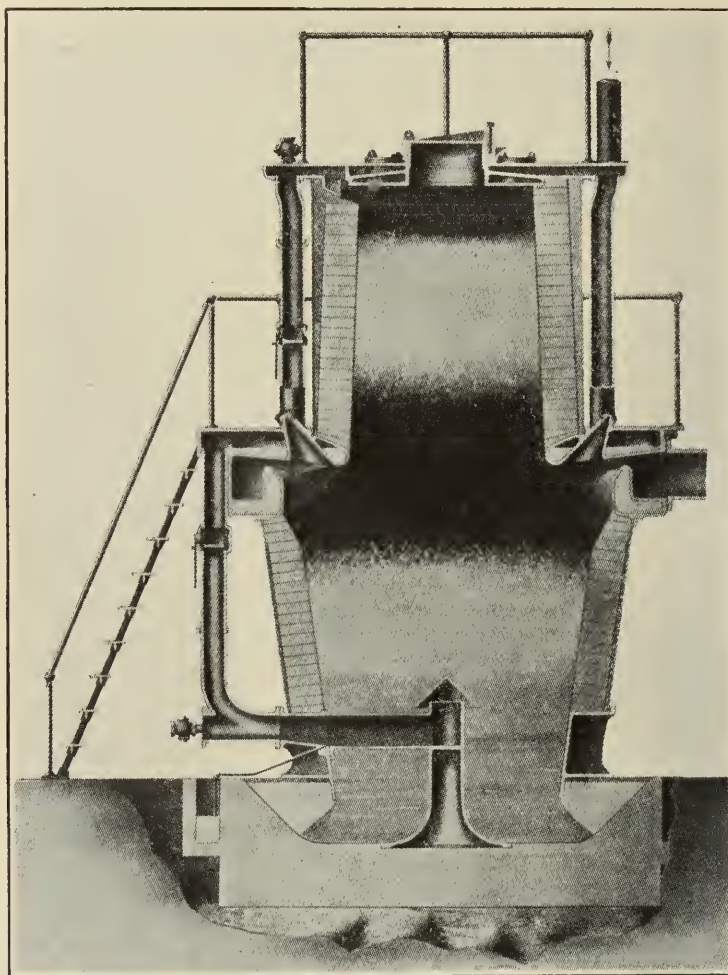
With the above system, after a certain period of operation, the tarry compounds, dust, soot, etc., tend to clog the fuel bed and the pull on the exhaustor increases. Under normal conditions, the average pull is from 5 to 6 inches of water, increasing steadily.

FIG. 13.



When the pull has risen to about 20 inches, the process of "shooting the bed" is gone through. The charging doors and the gas valve are closed, and steam under 60 to 80 pounds pressure is turned on under the grate. This jet of steam shakes up the whole fuel bed and sends the dirt, dust, soot, etc., through the by-pass into the other gas generator. After the process is completed the

FIG. 14.



gas has a heat value of about 200 B. T. U. instead of 105 B. T. U.

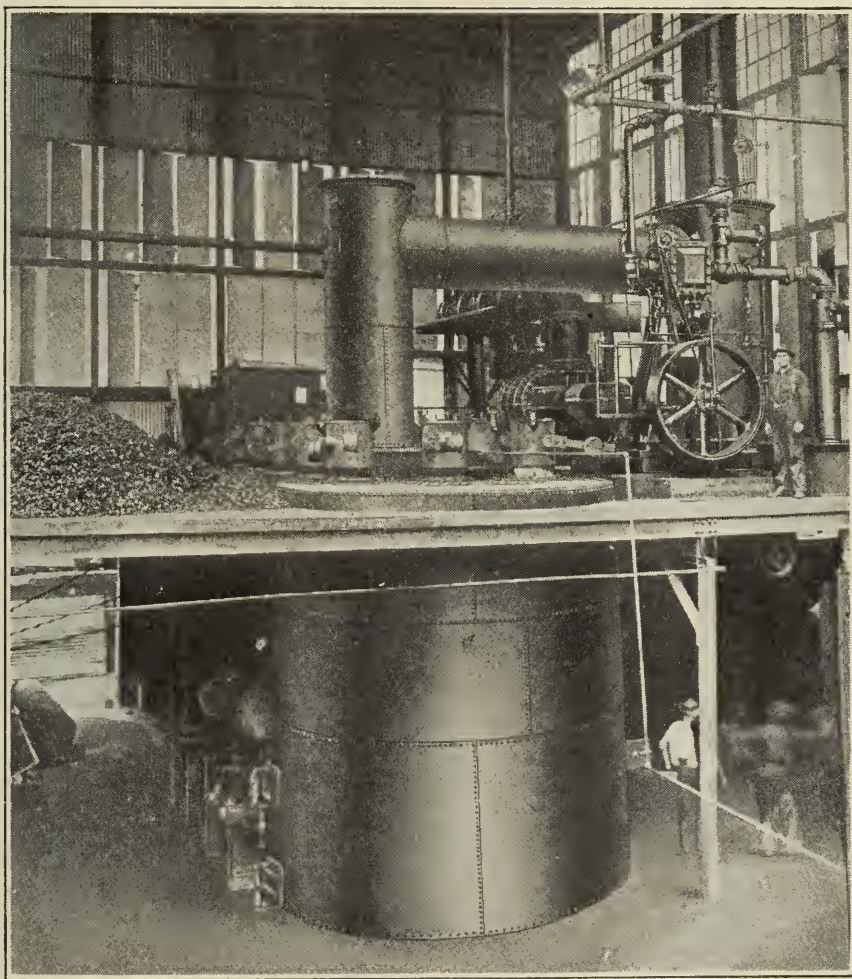
A double purpose is served with this type of plant, as two kinds of gas are produced—the first being commonly called air gas and the second water gas.

The system is used by a company in Boston which, however, requires no water gas, but simply gas for the engines. As a re-

sult, the bed is shot just as seldom as possible, sometimes not oftener than every six hours.

Another company uses a 4000-horsepower plant of this type. This company requires about 2000 horsepower for engine purposes, and the remainder of the gas for heating, tempering, an-

FIG. 15.



nealing, etc. In consequence, they shoot the bed just as often as possible, heating it up as rapidly as they can and then shooting it.

Tar can be satisfactorily converted into gas under the proper operating conditions. If, however, the temperature is not quite right, lamp black usually results.

In the type of plant described above, as the ash accumulates between the coke bed and the green fuel bed, the plant is intermittent and must be shut down in order to recharge. The charg-

FIG. 16.

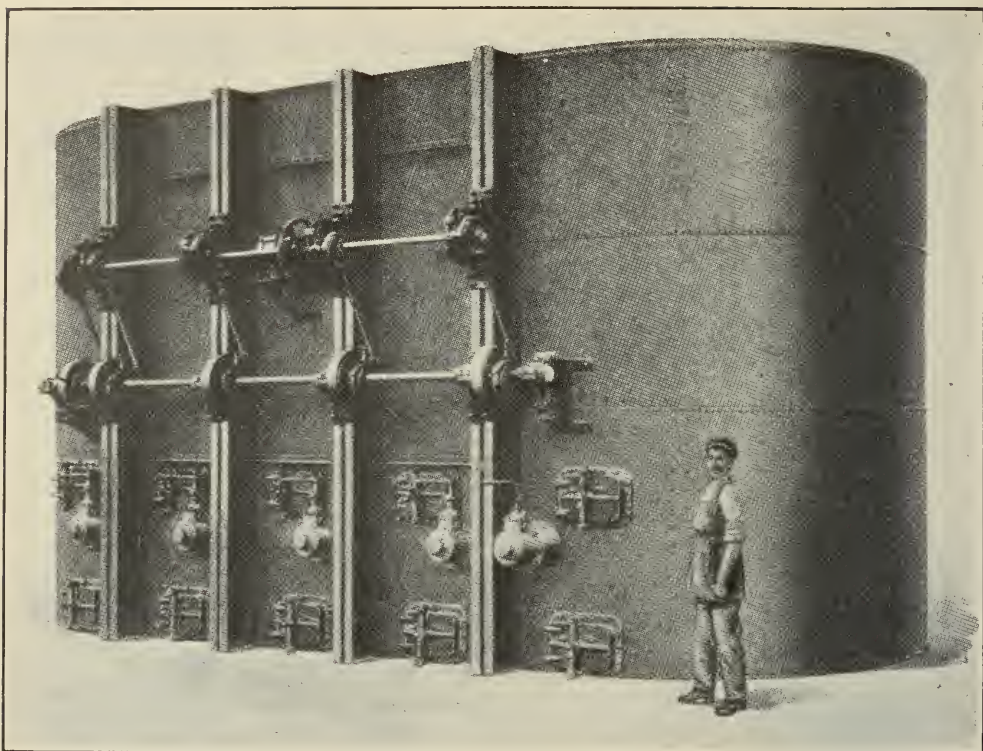
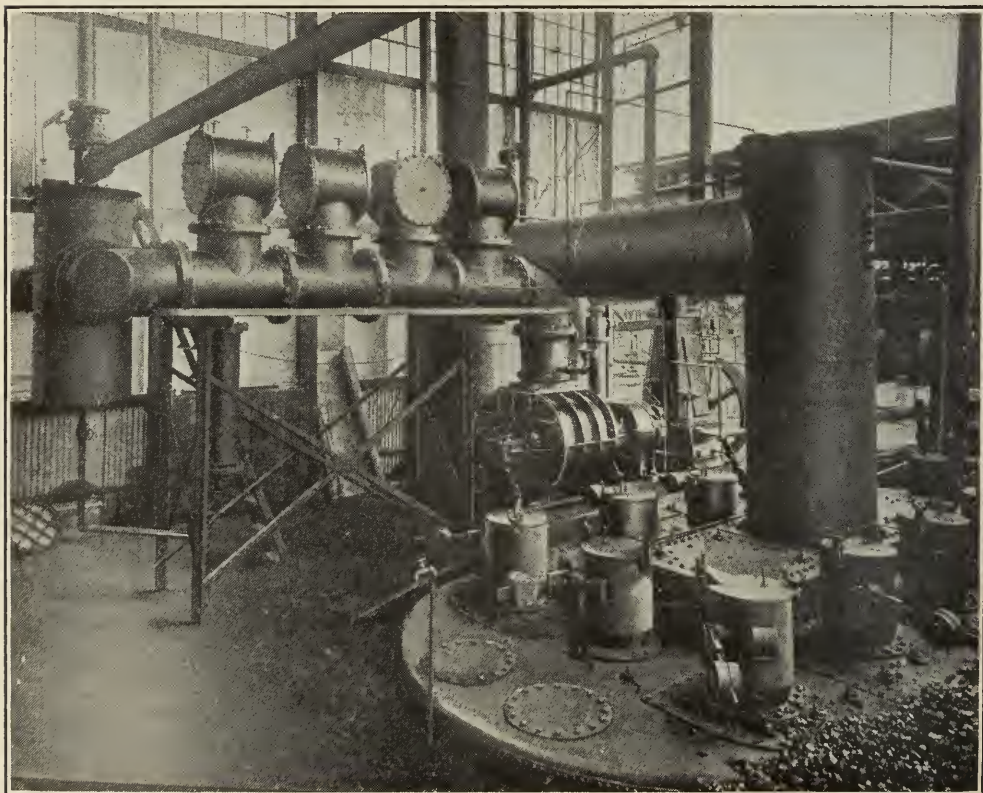


FIG. 17.

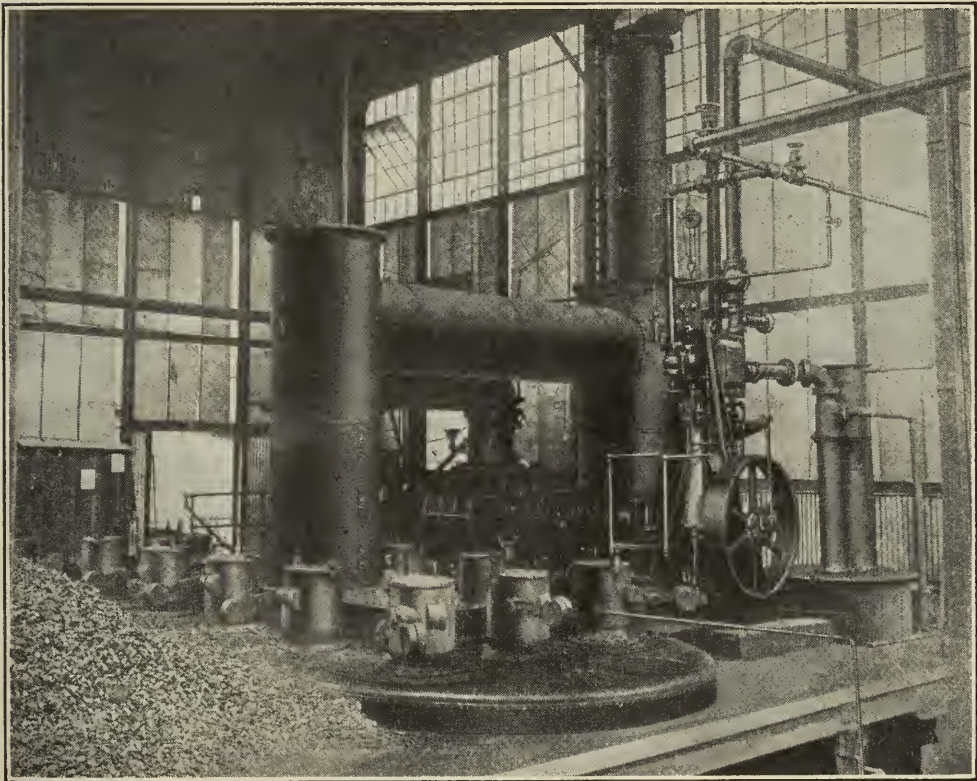


ing door may be opened and the coal charged directly into the producer, the whole operation being in full view of the operator.

Fig. 14 shows a type of producer with a double zone, in which are run two fuel beds, the object being to get rid of the tar. The coke which comes down through the upper zone becomes the main fuel for the lower zone.

A plant which was installed in the summer of 1913 and which illustrates the latest type of producer is shown in Fig. 15.

FIG. 18.



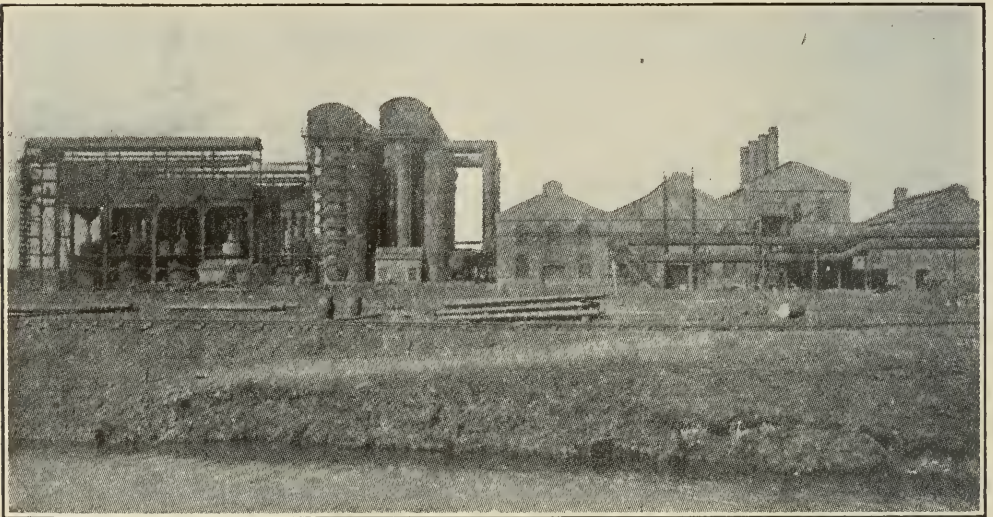
This producer is installed in Illinois, and is the largest single generator producer in the world. The producer proper is of simple construction and is made out of sheet steel and channels. It has semi-cylindrical ends and flat sides, as shown in Fig. 16. The capacity of the plant is forty tons of Illinois bituminous coal per twenty-four hours. The producer is equipped with what is known as the "Smith Type F Tar Extractor," having a capacity of 250,000 cubic feet per hour. This is not a centrifugal extractor, but consists of a double-tee arrangement; it has no moving parts and requires no water. The tar extractor in posi-

tion on the charging floor is shown in Fig. 17. In this figure may also be seen the gas exhauster. Fig. 18 is another view of the charging floor, showing the charging hoppers and the engine-driven gas pump.

FIG 19.



FIG. 20.



Centralization will undoubtedly become one of the essential factors in producer gas work, and even now railroads are considering the question of installing large central plants at the coal mines and utilizing the fuel there. Many important advantages are to be secured by the installation of such large plants, not the

least of which is the practical elimination of the smoke nuisance. A striking contrast between the old coal-burning methods and modern producer practice is illustrated in Figs. 19 and 20. Fig. 19 shows a typical view of coal plants in Staffordshire, England, and Fig. 20 shows a 16,000-horsepower producer gas station at Dudley Port, Staffordshire (recently enlarged to about 30,000 H. P.). This gas plant is one of the largest in the world. It is run as a by-product plant, and produces about 90 pounds of sulphate of ammonia per ton of coal. The gas is sold at a price which would correspond to 14 cents per 1000 cubic foot for city gas.

High-frequency Spectra of the Elements. H. G. J. MOSELY. (*Phil. Mag.*, xxvi, 1024.)—In the absence of any available method of spectrum analysis, the characteristic types of Röntgen radiation, which an atom emits when suitably excited, have hitherto been described in terms of their absorption in aluminum. This paper contains a description of a method of photographing the high-frequency spectra, which makes the analysis of the Röntgen rays as simple as any other branch of spectroscopy. It is intended first to make a general survey of the principal types of high-frequency radiation and then to examine the spectra of a few elements in greater detail and with great accuracy. The results already obtained show that such data have an important bearing on the question of the internal structure of the atom, and strongly support the views of Rutherford and of Bohr. Kaye has shown that an element excited by a stream of sufficiently rapid kathode rays emits its characteristic Röntgen reaction. He used as targets a number of substances mounted on a truck inside an exhausted tube, a magnetic device enabling each target to be brought in turn into the line of fire. This apparatus was modified to suit the present work. The kathode stream was concentrated on to a small area of the target, and a platinum plate with a fine vertical slit was placed immediately in front of the part bombarded. The tube was exhausted by a Gaede pump, charcoal in liquid air was also used sometimes to remove water vapor. The Röntgen rays after passing through the slit, emerged through an aluminum window 0.02 mm. thick. The rest of the radiation was shut off by a lead box which surrounded the tube. The rays fell on a cleavage face of a crystal of potassium ferrocyanide which was mounted on the prism table of a spectrometer. A photographic plate was mounted on the spectrometer arm, and both the plate and slit, S , were 17 cm. from the axis. If P is the part of the crystal where the radiation strikes the surface, and L the line on the photographic plate corresponding to radiation of definite frequency with glancing angle of incidence θ , then

$2\theta = 180^\circ - SPL = 180^\circ - SAL$, A being the position of the axis of the spectrometer table. A method is given of determining the angle SAL . Hence θ is known. The following elements were examined: Pt, Ta, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, and Zn. The photographs show that the spectrum of each element consists of two lines. The stronger of these is called α and the weaker β . The lines found on any of the plates besides α and β were most probably due to impurities. No other lines have been found; but a search over a wide range of wave-lengths has been made for only one or two elements and perhaps prolonged exposures, which have not yet been tried, will show more complex spectra. The prevalence of lines due to impurities suggests that this may prove a powerful method of chemical analysis. Its advantage over ordinary spectroscopic methods lies in the simplicity of the spectra and the impossibility of one substance masking the radiation from another. The similarity of the different spectra is shown by the fact that the two lines α and β remain approximately constant, not only in relative intensity, but also in relative wave-length. The frequency of β increases slightly faster than that of α . The same two lines, α strong and β weak, constitute the rhodium spectrum examined by Bragg, and they are obviously closely related in some way. One or two photographs taken with the radiation from platinum gave results in good agreement with those obtained by the electrical method, but no trace of the elaborate system of bands described by De Broglie was encountered. A discussion, based on Bohr's theory of atomic structure, is given of the meaning of the wave-lengths found for the principal spectrum line α .

Direct Recovery of Ammonia as Sulphate, without Distillation. W. STROMMINGER. (*Stahl und Eisen*, xli, 1694.)—For removing tar from hot gases previous to the direct recovery of ammonia as sulphate, the author describes a scrubber composed of two superposed chambers containing washing-tar up to the level of an overflow. The gases, brought to the desired temperature by means of a spray of ammonia liquor, are admitted to a number of inverted troughs immersed in the tar, and having serrated lower edges; two perforated plates are also immersed in the tar to insure intimate contact between the gases and the tar. The gases pass first through the lower and then through the upper chamber, and in the latter there is a filter above the tar level, to retain any tar spray. The washing tar is renewed by the tar separated from the gas, and the surplus runs continuously from the overflows. This apparatus has been in use for sometime in connection with 120 coke ovens at Ruhrort. No tar could be detected in the gases leaving the scrubber, and the quantity of ammonia in the gases leaving the saturator was only 0.75 gramme per 100 cubic metres. The ammonium sulphate was of a good, gray color, and contained 25 per cent. NH_3 on leaving the hydroextractor.

LOCOMOTIVE SUPERHEATERS AND THEIR PERFORMANCE.*

BY

C. D. YOUNG,

Engineer of Tests, The Pennsylvania Railroad Company, Altoona, Pa.,
Member of the Institute.

DISCUSSION.

MR. S. M. VAUCLAIN, Vice-president, The Baldwin Locomotive Works.—I have listened with a great deal of advantage to Mr. Young's discourse on superheaters. The indicator diagrams shown by Mr. Young in connection with high superheat and low superheat are very instructive, and if shown more frequently would revive the controversy which existed many years ago and which caused considerable discussion among the engineers of the United States Navy as to the relative value of low superheat compared with high superheat, resulting at that time, I believe, in a preference for low superheat. However, I believe it has been definitely proven that, for the high steam pressures which we are now using, high superheat is more advantageous, especially for locomotives, than low superheat. Of course, with low superheat, we do not have the same difficulties to encounter in the way of the deterioration of the metals employed in the superheater structure, and the deterioration of the low-pressure superheater is usually due more to the careless manner in which it is attended to than to its construction. The first low-pressure superheater which we (The Baldwin Locomotive Works) applied to a locomotive is still in use, and has required very little, if any, repair, whereas later superheaters which we have applied—several years later—have corroded and have been abandoned, and the locomotives have either been returned to ordinary single-expansion locomotives or high superheat has been substituted.

On the Continent almost any locomotive of any importance is now fitted with the Schmidt type of superheater, which is a fire-tube superheater. More than one form of fire-tube superheater is used abroad, but in the main they are either a Schmidt superheater, an infringement of a Schmidt superheater, or a super-

* Continuation of article on page 83, vol. clxxviii, No. 1.

heater of a kind which may be considered an infringement of the Schmidt superheater. In this country many fire-tube superheaters have been devised, but they have all grown out of the idea advanced by Mr. Schmidt. In regard to the fire-tube superheaters, it is very pleasing to me to know that an inventor, even though he may be a foreigner, has been able to preserve and establish in general use an invention of so much value as we can attribute to the Schmidt superheater. I have, of course, opposed the Schmidt superheater at times in very many places—sometimes successfully and sometimes not successfully—but for commercial reasons only; and when those commercial reasons were removed I was very glad of the opportunity to admit that, for general use in locomotives, I considered the Schmidt superheater superior to our own type of low-pressure superheater or any other type of high superheater which we may have employed. Simplicity of construction and the general accessibility of the device also commend it, and in this particular device and in similar devices I feel that nothing has been left undone to make it not only accessible at all times, but easy of maintenance, and as a general thing it is never found fault with by the locomotive engineer who must use the locomotive, but is always spoken of very highly by him.

Now the advantage of using a superheater on a locomotive is, as Mr. Young states, to get more power out of the particular locomotive. That which gives a locomotive its power is its boiler, and any device which can be added to a locomotive to increase the effectiveness of its boiler increases beyond question the effectiveness of the locomotive. The original hauling power or starting power of a locomotive it is impossible to increase because that depends entirely upon the weight on drivers, but it is possible to increase the hauling power of the locomotive in tons and in speed of miles per hour—or, in other words, in horsepower. If you are developing your tractive power at forty miles, you can still increase the horsepower, for the horsepower depends upon the number of pounds of water you are able to evaporate in the boiler. If by a device such as the steam superheater you can get a certain horsepower with 20 per cent. less water or 30 per cent. less water, it is perfectly natural to suppose you can evaporate the same amount of water in this boiler and by the use of a superheater you can develop a speed of, say, 40 miles per hour and

haul 30 per cent. additional tons, and it is for this reason Mr. Young, I believe, makes the statement that the lighter-powered locomotives can have their hauling power increased by the addition of superheaters. But do not allow yourselves to be led astray by the fact that these locomotives can haul more tonnage because they can steam any more effectively, but they can haul more tonnage at the speed in miles per hour, and thus increase the earnings of the railroad company owning them accordingly and add to their own intrinsic value to that company. As locomotives have been increasing in size in the last few years, all of us have been struggling with the question of getting the greatest number of tons of freight over the road in a single unit, or at one train movement, and a train movement costs just the same whether it is large or small. The laws of the various States now prescribe the number of men that the railroad must carry to a train, and the principal number of these men are hauled in the caboose. The locomotive engineer really does the bulk of the work—when we dispose of the fireman—the conductor keeps tabs on his car numbers, and the remainder of the crew have a pleasant journey.

The advance in the weight of locomotives in this period has been phenomenal, and even though we thought that we had reached a fair size of locomotive—or a really large size—these locomotives do not prove quite so effective as their size should have made them. It was apparent to us that the reason for this is that we are not able to work the boilers at what they should do on account of the human equation—the human equation being the fireman. Therefore, the superheater man comes along, and applies superheaters to these particular locomotives, and we find we have a very much greater result in hauling trains at different speeds and in their general efficiency, although the demands of railroads for heavy cars and moving heavy tonnage have led us to go back and modify our compound system to include the superheater system, for the purpose of still further reducing the water rate per horsepower and adding to the hauling power of such a unit as can be conveniently employed. Such locomotives are constructed up to a tractive power capacity of about 100,000 pounds, and the limit is supposed to be reached, because even with automatic power we could not get the full capacity of a boiler; and, although it may not have been apparent to any of you here present that a Mallet locomotive, for size,

is a very much smaller type than any other locomotive in service, at the same speed at which these engines were operated and with the use of superheaters they seem to be a very desirable engine. Take the case of the automatic stoker; general opposition was made to the introduction of an automatic stoker, because it was said if a fireman was able to shovel the coal there was no necessity for applying automatic devices for this purpose. The result, however, of the experience with various automatic stokers has boiled the art down to probably one or two devices; one device especially is most effective, and, in my judgment, has solved the question of the compounding of locomotives. We have been able lately to construct, for one of the most progressive railroad presidents in the United States to-day, a locomotive of 160,000 pounds tractive force, and which, in our judgment, and from its ease of movement and its apparent life before any trial in service, is going to be a very successful unit of power. Now, such a locomotive has been arrived at by the careful and intelligent employment of the first principles of locomotive economy, the uniformity, similarity, and the continuity between the different sections. This locomotive is in three sections, with three pairs of cylinders, three sets of driving wheels, one tubular boiler, and an ordinary locomotive engineer and fireman. The compounding of the steam is in the ratio of two to one, which ratio is suitable for superheated steam. The superheater used is a Schmidt superheater similar to the one shown to you to-night by Mr. Young, and is capable of reducing the water rate from 24 pounds to 16 pounds under proper conditions. And, in addition to that, this locomotive has been equipped with a mechanical stoker for supplying coal to the fire and properly distributing it over the surface of the fire; it works admirably, and is successful in every way for firing this locomotive, which will require about 11,000 pounds of coal per hour. No effort whatever on the part of the fireman, with the exception of properly attending to the valves running the engine which drives the firing mechanism, is necessary.

Therefore, you see that, at the present time enjoying the advantages of these economical mechanical inventions of the past one hundred years, the future generation, commencing now in the year 1914, is going to really build large units of power for railroad transportation, and in a few years from now we will look back upon these insignificant pigmies with which we have

been transporting trains throughout this country and smile that we did not tumble to these various inventions many years ago.

MR. F. H. CLARK, General Superintendent of Motive Power, Baltimore & Ohio Railroad.—There is very little more that I can say that would be of interest to the members. Mr. Young's paper covers pretty well the theoretical side of the matter, and he explains very clearly some things that I haven't understood, or had understood imperfectly, perhaps, and, on the whole, I think it is the best superheater paper I have ever heard—and I have heard quite a number of them—because it is so up-to-date, and it gives a great deal of information derived in a very scientific and accurate way.

I do not think there are any comments on the paper that I care to make. I am here to-night more as a learner and listener than for any other purpose, and I am very glad, indeed, to be here.

MR. C. B. YOUNG, Chicago, Burlington & Quincy Railroad.—I think there is nothing that I can add to Mr. C. D. Young's paper on this subject.

His work on superheat has been far in excess of any work that I know of by any other individual. He has delivered a paper which I do not feel competent to discuss.

MR. GEORGE L. BOURNE, Vice-president, Locomotive Superheater Co.—I think, as Mr. Clark stated, Mr. Young has covered this subject so well that there is hardly any room for discussion. I very much appreciate the opportunity of being here and listening to the paper, and it is probable that very few appreciate the amount of research work and trouble that Mr. Young has undertaken in going so deeply into the prior art and history of locomotive superheaters.

In studying the early efforts in the prior art, additional light might be thrown upon the earlier designs of superheaters, particularly those which resemble the later types in use to-day. In studying the earlier designs, as Mr. Young has shown them, you cannot help being impressed with the fact that the investigators, while they were working along similar lines that we are following to-day, did not seem to be in full possession of just what was necessary for the practical operation and maintenance of a smoke-tube superheater. A close analysis of the de Montcheuil design discloses the fact that this inventor's only idea in adopting a bent

tube, either entering or coming from the smoke-flue, was simply that he had to get into a smoke-flue in order to do his superheating. He realized that, and he also realized that after he got in he had to get to the cylinder in some way. Other than that, I don't see that there can be any similarity between the de Montcheuil design and the modern smoke-tube superheaters. In accomplishing the above end of the interchangeability of the units was sacrificed, and the arrangement of the units in the boiler was so complicated that they could not be detached from the heater selectively, but had to be withdrawn in the respective reverse order from which they were applied. In other words, the last unit applied would have to be taken out first.

It is also somewhat interesting, by reference to Dr. Schmidt's design, to note that it has hardly been changed in any way not exactly as we use it in this country, but as it is used in Europe. The difference between European and American practice is in the matter of detail, and is accounted for by a difference in maintenance and operating conditions.

It might be of passing interest to know that the courts in Europe have also held that de Montcheuil in no way anticipated the fundamental idea of the single- or double-loop superheater, having its ends bent to the header and detachably fastened, as is the standard practice in this country. We know from a practical standpoint that in order for a superheater of this type, having units in the smoke-flues, to be not only satisfactory as a superheater, but practical in operation and maintenance, the units must be easily detached. Any of you who are familiar with the maintenance of a locomotive know that it needs attention at some times, and the facility with which this attention could be given, I believe, was one of the principal reasons for the success of what is known as the Schmidt design. Schmidt fortunately realized that it wasn't so much a question of engineering practice, but in the design he produced at that time, he was working to what he knew would be a permanent mechanical arrangement.

With reference to smoke-tube superheater designs where side heaters are employed, practical experience has disclosed the fact that disastrous wire-drawing may always be expected, and this is corroborated by the general application of cross-over pipes, where these designs are being used, in an endeavor to overcome the wire-drawing effect.

Mr. Young's investigation on the varying length of units is of much interest, and it is pleasing to know that the results obtained by him corroborate not only the engineering practice of to-day, but also the results of numerous European tests which were undertaken in past years by the European Schmidt Company.

As to the varying lengths of the return loop, it is very essential, in studying this question, that the complete range of the operation of the locomotive be considered. In other words, what might be an ideal length of return loop for an engine operating at 15 per cent. cut-off would not be so ideal a length for an engine at 50 per cent. cut-off; so that in designing a superheater for a locomotive, the superheater engineer or whoever is responsible for the design has to take into consideration the varying conditions under which the engine will be operated. Admitting, for the sake of argument, that at certain times the temperature of the steam in the return loop is slightly above that of the flue gases, the extremely low conductivity of superheated steam will not permit of much heat transfer at the slightly varying temperatures. On the other hand, however, when the engine is working to a reasonable capacity, the extra length of return loop is essential and necessary in order to permit of complete drying out of the saturated steam, which has a relatively high conductivity, or, in other words, to permit, preparatory to the superheating, or the conversion of the fluid into a perfect gas by the attainment of a high degree of temperature, the elimination of the wet-core, which has always bothered the superheating engineer.

Mr. Young spoke on the question of a higher degree of superheat. So far as the superheater company is concerned, that is just a question of when the American railroad mechanical man believes he has come to the point where he will have no difficulty in operating an engine with, say, 750° total temperature. Now, with regard to the varying types of units, if the attainment of a high degree of superheated steam efficiency were all that entered into the problem, the design of units looped as shown in Fig. A, would satisfactorily fill the requirement. In other words, that particular design of unit would permit of escaping from the saturated side of the header entering in the path of the gases and remaining there as long as possible, collecting such superheat from the lower temperatures at that end of the flue, passing through to higher temperatures, and in order that we might

retain the maximum temperature of the steam, we would deliver the steam from the path of the gases as quickly as we could. That would be as near an ideal unit as we believe could be secured in the smoke-tube superheater, but I wouldn't like to say what I think as to its practicability or as to its maintenance. And there is another point: The conditions are so variable in locomotive operation that it would be rather hazardous to base a design upon any particular steam consumption. It must be remembered that the superheater company has to take the locomotive boiler as it is, and do the best it can. We have restrictions, and about the best we can get out of the average boiler under the operating conditions we have to contend with in American practice, and all that we believe is desired under American operating conditions, is approximately 650° , an average of from 600° to 625° , except at long cut-off and fairly high piston speed, and we don't wish to go over 650 . It might be of interest to know that in

FIG. A.



some of the European countries where they have been operating superheater engines for some eight to ten years they have arrived at the stage where they say, "We would like to have a little more superheat. Our coal costs a great deal of money, and if we can get a horsepower for 16 or 17 pounds of steam with 650° , why we would like to get it just a little lower." And there are quite a number of engines that are operating with total temperatures in the neighborhood of from about 725° to 740° . Thank you, gentlemen.

MR. GEO. M. BASFORD, American Locomotive Co.—I hardly feel competent to discuss this paper of Mr. Young's. I should like to say, however, a word in appreciation of the paper itself, and of the magnificent testing work which made possible the presentation of these data this evening. I should also like to say a word of appreciation of the Pennsylvania Railroad Company and its thoroughgoing methods which make these tests possible, and of the great generosity of that railroad company and its pro-

fessional spirit in bringing this information out so quickly and giving it so freely to the world.

I certainly appreciate being here to-night, as a privileged listener, and I am sorry that I cannot add anything to the material information on the subject.

MR. H. B. OATLEY, Locomotive Superheater Co.—I agree with all that the speakers have said as to the value of the paper Mr. Young has presented. There is no contribution to the literature of the locomotive—and the locomotive superheater in particular—that has added so much as this paper. The historical part of it is of especial value, and will become more so as time goes on. The data that have been brought out, as Mr. Basford has stated, from the Altoona testing plant, are recognized throughout the world. I recently came across some of the English engineering papers that referred to the tests, and the leading engineering association of Great Britain has recognized the value of these data for European roads. At the particular time the question came up, the topic of this evening was under discussion there, and it was regretted that they did not have in their own country data on superheaters such as have been presented from Altoona. They did not at that time have the particular series of tests that Mr. Young has given to-night.

The points that Mr. Bourne has brought out I think cover most everything that I could say.

The reference that was made in the paper to the possibility of an improvement, by some modification in the form of the units, bears with it, I think, a lot of uncertainties. It would demonstrate that a lot of changes could be made in the units that were going to decrease the efficiency of the superheater and of the boiler, and naturally of the locomotive as a whole. Whether there can be any improvements as mentioned in the statement Mr. Bourne has made seems open to discussion.

One point that occurs to me is in connection with the series of tests that were run on what, I think, might be termed the half and three-quarter returns. By shortening the return loop and moving the front return bend back into the flue a change in the area for the gases is brought about ahead of the maximum obstruction. In practice I believe that this wouldn't be as beneficial as it showed up on the testing plant, for the reason that flues would be more likely to clog up, which would decrease effi-

ciency. I understand that on each test they insured clean flues by having blown them out after a run of only an hour or an hour and a half. To me it would seem a decided disadvantage to shorten the unit in this manner.

I don't know as there are any other points that I could take up without consuming altogether too much time. I thank you for the privilege of speaking here this evening.

MR. OLIVER CROMWELL.—I think the profession will be very grateful to Mr. Young for this paper, and the pains he has taken.

There is one other side we might dwell on that probably would be of benefit to the railroads. A few years back it had become quite a serious question to employ labor for stoking the locomotives. I believe in the future this question is going to be very easily solved when they learn that there is no particular manual labor in connection with the firing of a locomotive. That is going to be a great help in solving this phase of transportation, and I believe the railroads and the locomotive manufacturers would do well to very thoroughly spread these views among the locomotive firemen of this country, and it will encourage a better class of young men to enter the service, with the net result of a decided improvement in the man who operates the machine.

MR. G. R. HENDERSON, Consulting Engineer, The Baldwin Locomotive Works.—There is one point that has not been brought out especially, and if we can get any information on it I think it would be very interesting, and that is: what relation does the velocity of the steam in the superheater pipes bear to the superheat? We are generally accustomed to thinking of material that it will get hotter the longer it is exposed to a heat, but there have been statements made at times that the superheat of the steam was really increased by causing it to flow through the pipes with a greater velocity.

Now it was shown on these slides to-night—some of these curves—that with the greater velocity of the steam when the boiler increases, for instance, from 25,000 to 55,000 pounds of water per hour, there was an increase in the superheat, but it must also be true—it was shown in the tables—that there was a very large increase of heat in the smoke-box, and also in the fire-box, and, of course, in the flues. Now a large part of that increased superheat was due to the increased temperature which these superheater flues had obtained. I do not know whether

any experiments have been made on this subject or not. If anyone here knows of them, I think it will be very interesting to have some testimony on them to-night.

MR. OATLEY.—It is very difficult to get any figures on that. I think probably Mr. Young will be able to answer that fully, or at least very much more fully than anyone else, because they must have made some analyses from the results they get at the testing plant.

A MEMBER.—I would like to ask how much superheat was induced at the time the exhaust valve was opened. I cannot see where there is any gain with the superheat going out of the exhaust valve.

MR YOUNG.—Mr. Henderson has raised a question as to the effect of velocity of flow upon the superheat. We have not done any direct work on the question, but we have information which indicates that unless a high velocity is provided in the transmission pipes for superheated steam there will be considerable loss; and if that is the case, it would seem as though the converse would be true, namely, that high velocity would be required in order to prevent loss of superheat. In other words, the maximum superheat would probably be obtained for a given heating surface in a given arrangement with the tube shown by Mr. Bourne; in this the direction of the steam is purposely reversed so as to get a high velocity as it returns, and break down what is known as the wet core of the superheated steam pipe due to the low conductivity of superheated steam. The steam must be broken up, and it was really with this thought in mind that the experiments with the spiral tubes were made. In the spiral tube, the thought was that it would break the wet core in the unit, and in that way influence the primary conductivity of the steam passing through; but as you saw from the experiments with that tube, this wouldn't apply in stationary practice. With a locomotive, there are no advantages to be gained by the slight increase that might be obtained in steaming action. It wasn't a desirable condition. In other words, we lost power, and anything that detracts from the power of a locomotive is detrimental to the purpose, for the locomotive is built for power and the power depends upon the boiler. It is unfortunate we haven't any information, but I believe this: that the more you reverse the steam without excessive

wire drawing, the better the superheat will be for a given superheating surface.

In stationary practice there is one form of superheater used very extensively abroad and in this country, in which the velocity is apparently made high by introducing a core in the unit so as to expose the steam to as thin a surface of metal as possible. In other words, the core in the unit breaks down the steam as it flows through.

A question is raised as to the temperature of superheat in the exhaust. We have made experiments at the testing plant in order to determine this question. To my knowledge, there is no device made that would record the temperature of the exhaust steam. The steam passes through a piston valve to the cylinders and thence through the valve again and out, but it is almost impossible to locate a thermometer except in the exhaust passage. Admission and exhaust are through a common passage, and therefore to get a true temperature of the steam at point of release is almost impossible unless you have a thermo-couple introduced and removed at each stroke. We have found, however, that we can obtain economy—and good economy—with fairly high superheat going out of the stack. Of course, that design which has produced the least waste would probably be the preferred design, but the load of a locomotive varies from practically nothing when drifting to its maximum at high speeds, or to a maximum at low speeds with very heavy load, and, therefore, the question of the amount of superheat is largely one of practice in maintaining the lubricant and the packing in the parts, rather than what superheat is discharged from the exhaust. In another bulletin, issued by the locomotive testing plant, we have shown the effect of high exhaust temperatures, and we find that with high superheat and short cut-off, even though we have considerable superheat in the exhaust the economies are considerable and the water rate is apparently little affected by the superheat which leaves at that point. Our readings show that the superheat in the exhaust will never be less than 15° , as measured, and will run as high as 70° , the temperature at admission being from 160° of superheat up to 300° of superheat. Of course, the longer the cut-off the greater the loss, both due to the lack of expansion in the cylinder and to

the fact that the shell has not the time to lose its temperature at the exhaust.

A MEMBER.—What kind of oil have you found best for use with the superheater, what kind in the piston, and what kind of packing?

MR YOUNG.—We use a petroleum oil compound having a flash point of about 575° , mixed with from 10 per cent. to 20 per cent. animal fat. The particular trouble is in maintaining the lubrication at the time the engine is running and when it is drifting. The main difficulty is that the heavy gases are frequently dragged into the cylinder, and they present a coat of carbon, so that the wear is very rapid. This practice seems to indicate that a close-grained cast iron, rather hard, will give the greatest service life. A casting should be just about as hard as can be machined to produce the proper surface. It is our practice to introduce oil with a hydrostatic lubricator, but we are experimenting with a mechanical lubricator which will introduce the oil regularly, and, so far as our experiments have gone it would appear that mechanical lubricators carefully handled will produce better results than hydrostatic lubricators.

We use for piston packing a soft metal. This gives considerable trouble when the engines are operated for a long time with long cut-off. We have no trouble in our valve steam packing, due to the fact that we use inside admission.

A MEMBER.—I have never thought of the possibility of using any animal fat in the oil, because we have such high temperatures. I use a mineral oil.

MR. YOUNG.—The reason we do that is frequently when engines are moved about we supply a small amount of animal fat, and under those conditions we will be sure after the engine gets on the road it will adhere, and the animal fat is used on superheated steam engines.

A MEMBER.—It might be a good idea when the engine is drifting to put your saturated steam in the cylinder. I have done that, and I don't think you would have any trouble.

MR. YOUNG.—I think that is a very good remedy for our troubles. I am sure there is no invention on the market that will do so.

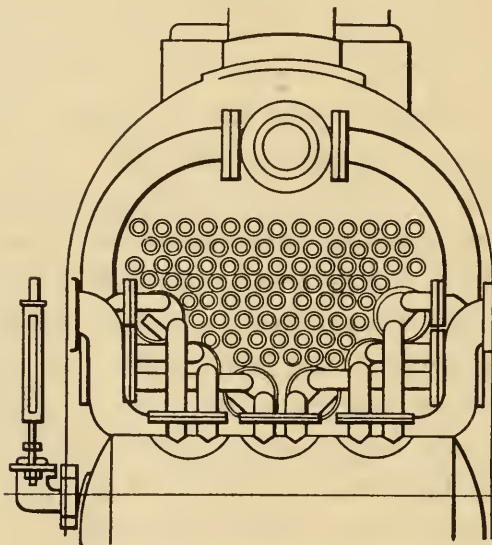
MR. HENDERSON.—This has been a very instructive presentation, and especially we appreciate the fact that Mr. Young has

given us this talk just as he is convalescing from a very severe sickness, and I should like, as a recognition of that, to take a rising vote of thanks to Mr. Young for his efforts in presenting to us to-night this very interesting paper.

CORRECTION.

Vol. 178, page 5, Fig. 3, substitute the following:

FIG. 3.



DE MONTCHEUIL'S SUPERHEATER, 1850.

Shrinkage of Alloys. ANON. (*Amer. Mach.*, xl, No. 22, 938.)—The excessive shrinkage of brass or bronze alloys necessitates a core which will be crushed readily by the molten metal. Large cores should be made with a soft interior, and this is generally accomplished by filling the interior of the core with cinders, powdered coke, or similar material. The core material must be fine, and this requires the use of finer sands for brass-foundry cores than those usually used in iron foundry work. When a brass casting has been poured and is shaken from the mold, care should be taken to keep the core sand from mixing with the molding sand. The cores for brass and bronze castings are sometimes blown out by shaking out the molds while the castings are still fairly hot, and then dipping the castings in water. The steam generated in the cores blows out the core sand, and gives the castings a better color. Iron castings would be broken by this treatment, but brass castings are rendered softer.

**CELEBRATION OF THE THIRTIETH ANNIVERSARY
OF THE INTERNATIONAL ELECTRICAL EXHIBI-
TION, HELD IN PHILADELPHIA IN 1884, UNDER
THE AUSPICES OF THE FRANKLIN INSTITUTE.**

THE National Electric Light Association holding its thirty-seventh annual meeting in Philadelphia the week beginning June 1st, and this year being the thirtieth anniversary of the above Exhibition, the officers of the association felt that some part of their meeting should be devoted to the commemorative observance of the event; accordingly the evening of Wednesday, June 3rd, was set aside for this purpose, and the Institute invited to conduct the meeting. Invitations were extended to the members of the National Conference of Electricians of 1884, the Committee on Exhibitions, the Board of Examiners, the Guarantors and Exhibitors, and others taking a prominent part in this exhibition. Among those invited to speak were Messrs. Brush, Sprague and Rice. In introducing Mr. Rice, President Clark, of the Institute, who presided said:

“Gentlemen, and members of the National Electric Light Association, and ladies: This meeting is in commemoration of the International Electrical Exhibition, held in Philadelphia thirty years ago, under the auspices of The Franklin Institute for the Promotion of the Mechanic Arts.

“The fortuitous circumstance of my present occupancy of the office of president of the Institute is solely responsible for my presence in the company of the distinguished scientists now before you, and for my having the honor of presiding over this notable gathering. But however accidental may be my presence at a gathering of the notables of the electrical industry, the presence of The Franklin Institute is appropriate and logical, and this not alone because of its controlling influence in the great Exhibition of 1884. When and wherever the devotees of your wonderful and wonder-working art are gathered, there, if the galaxy be complete, will be found the spirit of the great Franklin and the bodily presence of the venerable Institute that bears his

name. Not one of you—in whatever of the many branches of the electric science you labor—can trace the progress of your art back to its origin and not come in contact with this old electric generator [here points to the Franklin electrical machine on exhibition], designed, built, and used by Benjamin Franklin; and few of you upon such a quest can escape passing through the classic building on Seventh Street which is the home of the Institute.

“For two generations before the beginning of what may be called the electric age—the age that knew Edison and Bell and Weston and Brush and these other gentlemen in their early youth; for more than a generation before the Atlantic cable was laid; for a period beginning while the immortal Morse was still making indifferent marble statues, and the dream of a girdle about the earth had not come to him—for all that time, and ever since, The Franklin Institute has been promoting the science of electricity. Recording, disseminating, illustrating, encouraging, and rewarding, it has rendered continuing service to four generations. The science and art of electric generation, distribution, and utilization, no more than any other of the mechanic arts or sciences, can write its own comprehensive history and escape acknowledgment of obligation to the Institute and to the great man whose name it bears.

“The greatest individual service rendered to the electric art and science by The Franklin Institute was the International Electrical Exhibition that we are commemorating to-night.

“In the presence of the many gentlemen wise in the science and skilled in the art of electrical generation and utilization, who helped to make the Exhibition a success, and have since won fame by their contributions to the knowledge of electricity, it does not become me to describe the Exhibition, or to comment upon its influence. Fortunately for the success of this meeting, and for the fame of the Institute, there are men present, distinguished in your science, who can appropriately do this.

“Your industry, which had its beginnings within my generation, and has grown with unparalleled rapidity, offered opportunity for the exercise of the highest talents of men with combined engineering and administrative ability. The gentleman who is to make the first address this evening has given ample evidence, during the last thirty years, of possessing engineering

ability of a high order. The position that he holds to-day is proof conclusive of his possession of administrative and executive ability. I have great pleasure in introducing Mr. E. W. Rice, Jr., president of the General Electric Company."

MR. E. W. RICE, JR.: "Ladies and gentlemen, when I was asked by your chairman to come here to-night and make a short address in commemoration of this anniversary, I hesitated. It seemed to me that thirty years, a long time in the history of our industry, was so long that I could hardly trust my memory as to the events which occurred at that remote time. I also hesitated because I had a natural reluctance to appear to be such a patriarch in the business as to have recollections of such, I may say, almost prehistoric times.

"However, I consoled myself by thinking that I could supplement my recollections by my imagination, but even that refuge has been destroyed, as your committee has brought here as witnesses men who were the mighty creators of our industry, men who were producing, inventing, and starting this industry when I was but a mere boy. There is no danger that their memories may be as accurate, as true, and as remarkable as their deeds, and I shall have to confine myself, therefore, rather closely, I fear, to the facts. In the invitation which your chairman sent to me, he made some complimentary remarks to the effect that I had taken a prominent part in that exhibition. I suppose that this conclusion came from the fact that he may have found my name associated with that of Professor Thomson in connection with the exhibit of the Thomson-Houston Company, and also that my name was upon the list of the conferrees of the International Conference of Electricians, which was held concurrently with the Exhibition. However, at that time I was so young—in fact, I think about the only honor I can claim in connection with that conference, perhaps, is the somewhat doubtful honor of being the youngest conferree. I plead, however, in extenuation, that I was a good boy and was properly 'seen but not heard.' It is rather difficult, even for those who have lived in those times, to look back and properly picture to themselves the conditions of our industry at that remote period.

"At that time there was not a single trolley car in operation anywhere in this city or in the country, or, so far as I am aware, throughout the whole world.

“The highest voltage that was used commercially (I will ask Mr. Brush to correct me if I am wrong) was about 2000 volts. The largest current that was mentioned—and this was only mentioned by the scientists of the conference, and mentioned with bated breath, as if it were something to be hoped for, the ultimate attainment—was 5000 ampères. The largest electrical generator was the Edison Jumbo, which was capable of operating, I believe, 1200 16-candle-power lamps. The largest engine prime mover was under 200 horse-power—I think under 150. I am speaking now of what was at the Exhibition. This was long before the days of the X-rays, of course; of automobiles and of flying machines.

“I sometimes think that the gospel of work was somewhat more popular, and it was necessary to bustle a little more than it is to-day, when some people seem to get along with talking a little, and with the policy of waiting and watching. That, however, has not yet afflicted our industry.

“My mind naturally runs to some of the old stories which were circulated in those days—naturally they were childish as the industry was young—the old pioneers well remember them, and perhaps some of you gentlemen may, but, at any rate, I hope you will forgive me for recalling them.

“One that was quite popular related to a shipment of a dynamo. One of the large manufacturing concerns had shipped a dynamo to an important customer, and sent a letter saying ‘I am shipping you a dynamo with 200 volts.’ And the reply came back, ‘We have received the dynamo, but where are the volts?’ That is a companion story to the one about receiving lamps without the ‘currents’ and without the ‘watts’ and few things of that kind.

“But I am rather digressing, and I will try to describe briefly some of the things which we exhibited. First, I will say something about the exhibit in which I was interested, that of the Thomson-Houston Company, with which I was associated. Our principal exhibits naturally consisted of several sizes of Thomson-Houston arc dynamos, arc lamps, and various fixtures which went to make up a system of arc lighting in those days. I quote as follows from the complimentary reference to our exhibition made in the General Report of the Chairman of the Committee on Exhibitions:

“ ‘No company presented a more systematic display of electric lighting machines and accessories than the Thomson-Houston Company, and it was particularly valuable from an educational point of view. The exhibit had been carefully set up in Lynn before it was brought to Philadelphia, and throughout gave evidence of the conception of a perfect organizer. Some of the instruments, with mechanism dissected, illustrating the principles involved in working their machinery, and the large solenoid showing curious magnetic effects, were the source of continued study by amateurs.’

“ The following is a rather incomplete list of some other exhibits which our company made :

“ Thomson film cutouts ;

“ Thomson vacuum cutouts ;

“ Thomson lightning arrester for dynamos ;

“ Special galvanometers for electric light circuits ;

“ 10-ampère arc-light circuit divided into two circuits with two series of arc lights of 5 ampères each ;

“ One motor dynamo ;

“ Small electric motor ;

“ Incandescent distributors for arc-light circuits ;

“ Thomson combined motor and alternating-current dynamo.

“ The above list is of interest as indicating the activities of one of the leading companies of those days. Motor-generators, especially direct coupled motor-generators, were then a great novelty, and one of the two motor-generators which we exhibited was a direct-current motor coupled directly to an alternating-current generator.

“ Lightning arresters for the protection of electric-light circuits were, I believe, introduced in the art by Professor Thomson, and at this time were quite a novelty.

“ The film coutout mentioned was the forerunner of the film cutout which has been so universally used on series incandescent lighting circuits.

“ The division of the 10-ampère arc-light circuit into two independent series circuits of 5 ampères or split circuits, a large electro-magnet or reactance coil, which showed a clear recognition on the part of Professor Thomson of the properties of reactance in an electric circuit, and was probably the first application of such a principle for such a commercial purpose. It

naturally attracted a great deal of attention. It is unnecessary to state that such a division of the electric circuit would not be possible without the use of reactances or large resistances.

"The electric motor was just beginning to be used commercially at the time of The Franklin Institute Exhibition. In addition to the motors which we exhibited, the Brush Company had three in operation, one running two looms and one driving a plating machine and one driving a fan for ventilating the general offices of the Exhibition. Almost all the large electric companies had one or more electric motors on exhibition.

"I particularly remember the exhibit of Frank J. Sprague, who showed a number of electric motors arranged for constant potential circuits which gave constant speed under variable load without any automatic regulator. Some of these motors had in addition to the regular shunt winding a few series turns arranged for differential action, the effect of which was to weaken the field just enough to give constant speed under the most extreme variations of load. I was very much impressed with the behavior of these motors and with the ingenuity of the method adopted by Sprague to produce a variable load. As indicating Sprague's enthusiasm and prophetic vision, I would also mention that he exhibited a motor for electric railway purposes with self-contained means for varying the mechanical effects as speed and power, and means for reversing the direction of rotation: this at a time when two principal railways of Philadelphia, the Union and Market Street Lines, were at work changing their entire system of something like twelve miles from horse cars to the cable system, and it was naturally several years before the famous Richmond installation or Van Depoele's first electric trolley installation at Toronto.

"Probably the most impressive exhibit was that given by a combination of the six companies operating at that time under Edison's patents. This exhibit occupied a large space and showed the Edison incandescent lighting system, a large Jumbo dynamo, and a particularly prominent feature was a pyramid 30 feet high, containing some 1200 Edison incandescent lamps, which attracted great attention when lighted, as it was at regular hours.

"In this connection I will risk another old story. A lady had just finished reading an account of the Edison display, when she laid down the paper with an expression of horror and said,

‘ I see that Edison is going to put in a thirty-ton dynamo ; I don’t think that should be permitted.’ After meditating awhile, the danger seemed even greater, and she exclaimed, ‘ Suppose some horrid fellow should throw a lighted cigar into this ; why, thirty tons of dynamite would blow up the whole city ! ’

“ I remember with interest that organ recitals were given at intervals upon an organ, the bellows of which was driven by an electric motor, and the pipes operated from a considerable distance through the medium of an electric keyboard.

“ The United States Electric Light Company exhibited a system which was largely representative of the genius of Edward Weston. This consisted of dynamo machines for arc and incandescent lighting, arc lamps, incandescent lamps, motors, instruments, etc.

“ In the Brush exhibit were shown not only the well-known Brush arc lighting system of dynamos, arc lamps, etc., but also the Swan incandescent lamps, and what was then a great novelty, the Brush storage battery. This was about the first bow for commercial favor of the storage battery in America.

“ Other well-known pioneers of the early days were there in great numbers, such as Van Depoele, Ball, Bernstein, Hochhausen, etc.

“ In addition to the exhibitors of electric light and power apparatus there was also a very interesting exhibit by the Western Electric Company of switchboards, magnetic call bells, cables, telegraph and telephone apparatus. The American Bell Company had a working telephone exchange system connecting with the exhibitors and all the subscribers of the Philadelphia Exchange, and a particularly interesting historical exhibit of the first telephone, the telephone of Bell exhibited at the Centennial Exhibition, carbon transmitters of Edison and Francis Blake, and the original telephone exchange switchboard.

“ The *Electrical World*, which was then in its infancy, had the great enterprise to print its weekly edition during the Exhibition by a press run by a small Daft electric motor, and claimed, and doubtless with its customary accuracy, that it was the first time that any journal was regularly printed by electricity.

“ However, my most vivid memories of this time were not of the buildings, machinery, and exhibits, but of the men, the great inventors, scientists, and the pioneers of those days, many

of whom have since passed away. I remember especially the meetings of the Conference of Electricians, the most commanding figure being that of Lord Kelvin—Sir William Thomson, as he was then known. At these meetings I had the great pleasure to listen to such men as Sir William Preece, Sylvanus Thompson, Simon Newcomb, who called the Conference to order and introduced the president of the Conference, Prof. Henry A. Rowland. I remember how thrilled I was by Rowland's opening address. Lord Kelvin, who followed, called Rowland's address 'an admirable exposition of the relations between pure science and the application of science to the wants of men.'

"The Conference which followed was, as I have stated, presided over by Professor Rowland, and was participated in by Lord Kelvin, Sir William Preece, Prof. Sylvanus Thompson, Prof. John Trowbridge, Prof. George F. Barker, Prof. Wm. A. Anthony, Prof. Elihu Thomson, Prof. Simon Newcomb, Mr. Frank J. Sprague, Mr. Nathaniel Keith, Mr. Thos. D. Lockwood, Prof. George Forbes, Prof. E. J. Houston, Prof. Alexander Graham Bell, and many others.

"Its most important work was the recommendation of the recognition by Congress of the ohm, the ampère, and the volt, following the Paris Conference. After this Professor Rowland read a long paper on the theory of the dynamo electric machine, full of valuable advice; it contained information and views much in advance of the times, and was not, I fear, fully understood. However, it contained definite and rather sharp criticisms of many designs which then existed, and provoked, as a consequence, a lively and at times a warm discussion by the various inventors who felt that their pet designs or theories had been criticised.

"A most interesting discussion followed the recommendation by Sir William Preece of the adoption of the 'watt' as the unit of power, and a further amplification of Sir William Preece's suggestion made by Professor Cress to call one thousand watts a 'kilowatt.' The term 'watt' was finally adopted by the Conference, but the adoption of the 'kilowatt,' while favorably considered, was postponed.

"I think the Exhibition and Conference had a wonderfully stimulating effect upon the design and manufacture of electrical measuring instruments of various kinds. The subject was most intelligently discussed by the Conference in establishing the ohm,

volt, and ampère, and considerable time was devoted to the discussion of the necessity of improved instruments and better methods of calibration.

“ Sir William Preece said, speaking of the need of the greater accuracy of measuring instruments, that ‘ I tried instruments from every maker known to be fairly accurate, yet I scarcely succeeded in obtaining instruments to record to an accuracy of five per cent. It was a common thing to find our ampère metres showing an error of ten per cent., but the volt meters were more accurate. At the present moment I do not know of a single instrument in England that can be bought from an instrument maker that has recorded upon it a certain scale that can be relied upon to within five per cent.’

“ Sir William Thomson, speaking upon the same subject, stated that ‘ we have at present ampère and volt meters which are not good even within two or three per cent., and sometimes not within ten per cent., of what they profess to be. There is a great difficulty in obtaining instruments which have the conditions of constancy in themselves, and when any one has prepared an instrument which has in itself the conditions of constancy it is exceedingly difficult to get the value of its coefficient determined.’

“ The scientists and practical workers in the electrical field at the Conference all felt the need of accurate, rugged instruments which would permit the accurate and speedy measurement of the various electrical quantities. How well the demand was met, particularly by Edward Weston, is a matter of history. I have always believed that the electrical industry owes much of its wonderfully rapid advancement to the accuracy and quickness with which we have been able to measure the various electrical quantities. Indeed, one has only to think of the time, expense, and difficulty incurred in making any other measurement, particularly of a mechanical nature, such as the measurement of the power consumed by a machine or the flow of steam or water, to realize the debt which we owe to electrical instruments. Indeed, the easiest and more accurate method of measuring mechanical power is now indirectly by electrical means.

“ I may be pardoned, perhaps, for saying that one of the most pleasant recollections which I retain of The Franklin Institute Exhibition is that three of my professors at the Central High School took such a prominent and important part in the work of

the Conference and of the Exhibition. Professor Houston was the Official Electrician of the Exhibition and Chairman of the Committee on Electrical Installation. Professor Snyder was Special Chief of Measurements, Testing, and Reports, and Chairman of the Committee on Conferences. They were both members of many other committees, and took a prominent part in the Electrical Conference. A very notable address was also made by Professor Snyder, recommending the establishment of a National Bureau of Standards adequate to the scientific and practical needs of the nation. Professor Thomson was the chief inventor of the Thomson-Houston Company, one of the exhibitors, and was also a member of the Conference of Electricians, and took a prominent part in its discussion.

“Professor Thomson, writing recently respecting the Exhibition, states that ‘The Franklin Institute Exhibition was the first exhibition in the country to be devoted to electricity alone, and during its continuance the first Electrical Conference came off. The Exhibition itself, as you will remember, was a unique collection of exhibits, showing practically the status of electrical work at that time in a fairly complete way, and the Electrical Conference referred to came at a time when great interest was being manifested all over the world in the future development of electrical applications.’

“One of the most remarkable features of The Franklin Institute Exhibition, which is perhaps unique in history, is that ‘the report of the Treasurer showed the Exhibition to have been a financial success. The entire expense of the erection of buildings, the cost of shafting, steam piping, as well as the running expenses, were promptly met’ and a ‘balance of some \$10,000 to \$20,000’ left in the Treasury. ‘This was accomplished without Government aid or the use of public moneys.’ In view of the fact that the Exhibition was in every other way a great success, the financial record is certainly refreshing and tempts one to believe that perhaps after all they knew how to do things better in some respects in the good old days.”

DR. WALTON CLARK: “Before the Exhibition of 1884, and for a hundred and thirty-five years previously, when 16-candle coal gas was a luxury, sold, perhaps, at \$2.50 a thousand cubic feet, but little used, sales per capita of 700 or 800 feet, we did not appreciate the influence and the value of bright lights, we did

not know that there was an arc light, and we did not know that a light equivalent to an arc light was as good as a policeman; in reality, we did not know what could be done for the protection of property and of innocents in our cities, until the gentleman who will speak next brought out his machine and his lamp. I do not know as much of the subject as you gentlemen do, but I know something of it, and I believe firmly that no man since the world began has done more for the protection of person and property in the great cities than Dr. Brush, whom I now have the pleasure of introducing."

DR. CHARLES F. BRUSH: "Mr. Chairman, ladies and gentlemen: When, two or three weeks ago, I was invited to come down here on this occasion and say a few words, I did not hesitate, as Mr. Rice says he did, but I promptly declined. Some of my friends were so good as to point out the pleasure that I would forego, and other considerations, and I consented to rearrange previous engagements, came down, and here I am. I will comfort you with the statement that I am not going to give you an address. I have endeavored to-day to ascertain from my friends what they would like me to say a few words about, but my efforts have been quite unavailing: they have not given me any hint. But we know we are commemorating the electrical exposition of 1884. That has been spoken of already, and, as most of you know much of the history of the development of the great electrical industries since that time, it occurs to me that perhaps I would better say a few words of the earlier history of these great industries which we are so familiar with to-day, especially because that may be summed up briefly, while their history since that time might well fill a library of many volumes.

"In speaking of the early history of electrical development in this country I cannot avoid being personal to some extent, and I hope you will pardon that, because at the time I became interested in the subject it was not much of a subject, and there were very few thinking of it, and any one who happened to take an interest in it was conspicuous for that reason, and could not say anything about it without being more or less personal.

"As this is partly a function of The Franklin Institute, too much cannot be said for that venerable and splendid institution. I think we may safely say that, in a way, the electrical industries as we know them to-day were born and fostered in that institu-

tion, and I have particularly in mind the year 1877, when the Institute became ambitious to own a dynamo electric machine, a thing very rare in those days, and invited such makers as there were in the world to send in their apparatus and compete for the sale.

“Professors Thomson and Houston, if I remember correctly, took entire charge of the electrical measurements, which extended over a period of several weeks, and the contest excited in Philadelphia great interest, and I think it may be justly said that the interest then aroused here and elsewhere indirectly started the growth of our great industries.

“That was in the summer or autumn of 1877. In the spring of 1878 there began to be some little indications of commercial activity in the field of electric lighting, and by the summer or autumn of 1878 there was considerable activity in this field; and it is interesting to note that a Philadelphian, Mr. John Wanamaker, lighted his great store almost wholly with electric arc lights. He had a plant by the autumn of that year, consisting, I think, of 20 arc lights of about the present size. That was far and away the largest electric lighting plant in the world, and it was in Philadelphia.

“Of course, some humorous things occurred in the early days of the industry. I remember one occasion when a small electric light plant, perhaps a 20-ampère light—which was large for those days—was shipped to Cincinnati by the then Telegraph Supply Company, to Dr. Longworth, an enterprising scientist of that city, and I went there to show him how to run the lamp. It was exhibited in front of the building in which he had his office, and, of course, attracted a great deal of attention. On the first evening when it was shown a large crowd of the natives gathered in front of his establishment, and you could hear various exclamations of delight. Here and there in the crowd you could hear some one person delivering a little impromptu lecture on the electric light, and he would have quite a hearing. You may, some of you, recall that in these early days the lamp that first made its appearance had a large solenoid at the top, through which ran a rod which carried the carbon. One man who had collected quite an audience pointed to the solenoid and said, ‘Gentlemen, that is the can that holds the oil.’ The lamp had two rods at the sides. He pointed to them and said, ‘Those are the tubes which convey

the oil from the can to the lamp.' He created quite a sensation, and his hearers went away feeling that they knew a whole lot about the electric light, although the speaker had said nothing about it at all.

"In the summer of that year an exhibition was held at the Union Steel Screw Works in Cleveland. A dynamo was exhibited there which operated four electric lights on separate circuits with the non-series lamps, and quite a large company of invited citizens was present to witness the exhibition. One of the most prominent of the old Clevelanders seemed to be greatly interested, and he pointed to the line wire between the lamps, which was bare copper then, and he asked me, 'How large is the hole in that little copper tube through which the electricity passes?' He was quite in earnest.

"The superintendent of the shop, one of those men who knows everything, looked for five minutes, perhaps, at the dynamo. There was more or less sparking on the commutator, as there always was on electric-light dynamo commutators, and then he was ready to tell me all about it. He said, 'The electricity in that thing is generated by that revolving business rubbing the air up against them iron blades,'—he called them, meaning the pole shoes of the magnets,—'just like you get sparks when you rub a cat's back.' I said this was a simple and beautiful theory, but it was not entirely right. However, that did not affect him at all. He said, 'It is perfectly clear; if you should run that thing in a vacuum, you would not get any electricity.' He seemed to be so happy in his state of mind, in his theory, that nothing further was said about it.

"Late in the fall of 1878 there first appeared the device known as the series arc lamp, and I think we may call that year, 1878, the banner year in the early history of the electrical industry, because it was that device which first made electric lighting from central stations commercially possible; I think we may regard that year as marking the birth of the electric lighting industry. Prior to that time the development of electric lighting was slow, but after that it was very rapid, and as early as the spring of 1879 the public square, a little park of about ten acres, in Cleveland, was lighted with twelve series arc lamps, and it has been lighted electrically ever since. I am quite sure that was the first electric street lighting in the world, on a commercial basis. And

that is not so very long ago—that is, it does not seem so to me, but it will to some of you. I was introduced a week or ten days ago at the opening of an electrical exhibition in Cleveland by a chairman who said he had the pleasure of introducing a gentleman who was familiar with the electrical industry in 1779. I promptly claimed an alibi before any one had a chance of asking me if I remembered the true inwardness of the Washington-hatchet story current at that time. I got in ahead of them; I wasn't asked.

“It is interesting to reflect that even at that time, 1879, when the industry had really made a start, we had no shop instruments such as we have now—no ammeters, voltmeters, and so on. We had to guess at almost everything. It was about 1881 when we first had instruments of that nature.

“Many references have been made to the electrical exposition that we are celebrating to-day, but it was my good fortune, my privilege, to attend an electrical exposition in Paris in 1881, which was perhaps the first of its kind in the world. It was held in the great Palace of Industry there, and was considered a great affair at the time, and it was. But while that was very early, I think we may say that most of the seeds of the great industries which have developed since were there. There were perhaps 100 arc lights and about as many incandescent lights, and all were used to light that great building, and it was thought they did it splendidly. And there were various types of dynamos, both alternating current and direct, and a few motors. And there was the telephone, of course. That was just beginning to attract great attention, and there was a crude form of storage battery which excited very much interest. There was a real trolley car, which ran a few hundred feet back and forth outside the building—when the electrical conditions were propitious—which was not very often—and it was always crowded with passengers, many of whom had waited a long time for a chance to get aboard—quite like the present-time practice.

“Going back a moment to the year 1878, which, as I said, was the birth year of our great industries, the year from which they started a vigorous growth, I imagine there was not invested in the whole of the electrical industries more than two or three hundred thousand dollars. I think that would be ample to represent them all, outside of the telegraph. In 1905, which was

27 years later, I had occasion to collect some data as to the amount of capital invested in the electrical industries at that time, and to my surprise I found it to be not less than four thousand million dollars in this country alone; that is about one hundred and fifty million dollars a year on an average, for the 27 years, or half a million dollars for every working day during the 27 years. Now, in the nine years since 1905, I imagine the investment has been, on an average, three times as rapid. I think we are within bounds in estimating that for the last nine years there has been something like a million and a half dollars of new capital going into the electrical industries every working day of that period; and the end, gentlemen, is nowhere in sight. I am glad it is not, because those who can will have the pleasure of seeing them develop, perhaps even more rapidly than we have. I know the hour is getting late, Mr. Chairman."

THE CHAIRMAN: "You have an all-night license."

DR. CHARLES F. BRUSH: "No, I don't want to talk all night, I did not intend to talk at all. Thank you, gentlemen."

THE CHAIRMAN: "The electric machine that Dr. Brush speaks of as having been sent to The Franklin Institute is now on the floor. We have always been glad it was not larger, because one day the current from that machine went through Elihu Thomson, and he fell to the floor.

"Many of us, those of us who are gray here, remember the single horse car that went 'jog, jog,' across the country, and we can compare its slow rate of progress, the few people it carried, with the present rapid transit between cities and to cities, but we owe it to men, one of whom is with us to-night, and who, I hope, will tell us what influence the Exhibition about thirty years ago had on the electrical trolley business. I have great pleasure in introducing to you Mr. Frank J. Sprague."

MR. FRANK J. SPRAGUE: "Mr. Chairman, ladies and gentlemen: I am going to talk less than most of my predecessors. I know that will be the most welcome news that I can give you. In fact, I begged to be excused entirely, because as I looked to the other side of the platform and saw that patient, grand old man of our electrical profession who once unceremoniously fired me, and afterwards was present at the award to me of the Edison Medal, and who, I know, while sitting there very patiently, is hoping this meeting will come to a close, I am reminded of a

little incident that happened on that aforesaid occasion. Tom Martin said to him, 'Did you hear any of this?' 'Not a word.' 'You must have enjoyed yourself.' 'I always do when I think by myself.'

"As I look about this association and see the representatives of that great industrial fabric which is misnamed the National Electric Light Association, I am reminded of the fact that it ought to be named the National Electric Light and Power Association, because it was predicted by those who interested themselves more particularly in power some years ago that our great central stations must become diversified suppliers of electrical energy for every purpose, and in time the demands for power would outpace that for electric lighting. I believe I am safe in saying that already in Chicago, possibly in this city, and in New York even now, the capacity connected up for power purposes is greater than the enormous total used for electric lighting.

"Your industry has been founded partly upon capital, but largely upon the efforts of inventors and engineers. Few inventions are the result of inspiration. They are simply engineering developments brought out at such period in answer to some impelling demand. It is said that necessity is the mother of invention. If that were a recent expression I think we could charge that phrase to the militant suffragists or the feminists. I hope, ladies, there are none of the latter in this audience, as the feminists have been defined as that class of individuals who hope for free love in a manless world.

"In this connection I am reminded of a far-away Indian tribe, visited by a man well known to most of us, Oscar T. Crosby, who resigned from the army to become associated with me in the construction of electric railroads in the early days, where a peculiar habit, the complement of polygamy, polyandry, exists. For economic reasons, the inheritance of land, or what-not, marriage is somewhat limited in degree. The eldest of a family of brothers, taking unto himself a wife, shares his privileges with his younger brothers. If necessity be the mother of inventions, it is polyandrous, because here and there throughout the world there often appears the same invention, and, as in the case of this tribe to which I have referred, if the child is one which is sufficiently attractive, we find that there are many parents claiming paternity for it, irrespective of the facts. Most

of us are inventors, engineers, or electricians, or what-not, partly because of environment and partly because of the early conditions in which we were placed. It was my good fortune to graduate from the United States Naval Academy in 1878. I hesitate to go back a third of a century; it doesn't look so long backward, but it is a devil of a distance ahead, and I remember the rise in the firmament of the names of Edison and Gray and Brush and Bell, which fired my young imagination. One day I wrote to Edison: 'May I stop and see you at Menlo Park? I want to show you an invention.' He replied favorably, and so I came to him with an invention of a telephone. He looked it over, criticised it somewhat, made a few rough sketches of a somewhat better plan, and I suddenly lost interest. He said, 'If you don't think I am right, go up in the laboratory and try it yourself.' I went up stairs, but after I had been there ten minutes I had forgotten all about the telephone, and was intensely interested in an incandescent lamp which Edison was developing. Later I went on a tour around the world, but I never lost sight of that vision of the coming electrical power, and I planned to leave the naval service. Finally I did get home in 1880 for my examinations, and I was delegated for service on a training ship to teach young ideas how to shoot, but I still thought of that electric light, and I said to myself, 'What a great opportunity this is to introduce it into the navy!' You know that then we midshipmen slept in hammocks and used tallow candles. I went down to the engine room and, casting my mechanical eye around, discovered an old single-acting steam pump for supplying the boilers, with a fly-wheel, a water cylinder at one end and a single steam cylinder at the other, and I thought to alter that pump into an engine that would light the ship. I sent to Edison to see if I could get hold of one of his early dynamos, as I wanted to try to light the *Minnesota* with electricity. He sent back word, with that horse-sense of his, and said that engine I wanted to use would run that dynamo so irregularly that the electric light would be damned forever on board ship.

"Two years afterward, in 1881-2, it was my privilege to be ordered to the second electrical exhibition which had been held; the one that Mr. Brush spoke about was at Paris. This second one was at Sydenham, the Crystal Palace, and there I became absorbed in admiration of the work of Mr. Edison, represented

at that time by Mr. Johnson. There was a battery of twelve machines, arranged in three groups, and requiring a total of about 100 horsepower to drive them. Remember that this was only thirty-two years ago, and to give you some idea of the advance from that date look to the electrical plant in this city, where you are now installing a single turbine unit weighing 600 tons, with a normal capacity of 35,000 kilowatts, nearly 7000 times larger than the unit machine shown by the Edison Company at the Sydenham Exhibition in 1882.

“It was my pleasure at that time to report to the Navy Department in these words regarding the Edison system:

“‘In the matter of making transmission of light and power a practical success, and bringing it home to everyday domestic economy, Mr. Edison, without doubt, has done more than all others.’

“But at this Exhibition there was not an electric railway, there was not an electric motor of any kind or character. There was no suggestion of anything, in matters of that kind, except the electric light.

“In 1884 came your Exhibition here in Philadelphia, and the only electric railway that was here was a small model railway put in by a Mr. Bidwell, I believe, deriving current from a brush passing through a slot, and operated within the building, and two years later, in Boston, New York, Philadelphia, and Baltimore, I was operating experimentally single electric cars with storage batteries.

“Van Depoele, now passed on to the beyond, and Leo Daft, who is still with us, had also become active, and it was my pleasure, in 1887, to inaugurate the pioneer modern Richmond trolley railroad, with what consequences in this art you now know.

“It has been stated that there was loom driving at this Exhibition. I have in my hand a cut from the first piece of cloth woven on a loom driven by a constant speed, non-sparking, constant potential motor, one of my earliest productions.

“The path of those who were active in the early developments has not always been an easy one. I remember some twenty-three years ago, prior to the introduction of the multiple-unit system in the operation of railways, and prior to determining what would be done on the subways of New York in

rapid transit, in order to overcome the activities of the elevated railroad owners in the city of New York, backed by newspapers of that city, and to prevent the extension of elevated railroads, I took it upon myself to publicly offer, at the expenditure of \$50,000, to put two electric trains in operation on the elevated railroad, one to be operated by a locomotive and one by motors under the cars, at speeds of forty miles an hour. This was intended to demonstrate that the first thing to be done in determining rapid transit was the acceptance of electricity as a motive power, but it took the rapid transit committee of that city many years to come to that conclusion. I know I attempted in 1886 and 1887, and then again in 1896, to interest the elevated railroads of New York in electrical operation. I twice offered, at my own expense, to make a demonstration of the multiple-unit possibilities with a full six- or eight-car train, but it fell upon deaf ears, and it was not until two years after such offers that the opportunity came commercially to make the first introduction of that system.

“One of the great ambitions of all of us has been to electrify the railroads of the world, especially the trunk line railroads. It has been a common prophecy of electrical engineers that main line railroads would be early electrified, and the steam locomotive thrown into the discard. Hopes have outpaced facts, for when the gilded electric giant—and gilded it must be because of the large amount of capital required—goes into the arena to meet its iron-clad opponent, the modern locomotive, on the basis of comparative economy of operation and capacity, it has been a hard row to hoe.

“In the urban, suburban, and interurban fields, and now also in terminal operation, electricity holds its own, because it deals with classes of traffic often impossible for like operation by steam; but when we get into the trunk line operated field we must then discard a great deal of existing investment, and must incur large investments at a time when money is very difficult to raise.

“Now, how is the advance going to be made? Right with you, gentlemen, lies in a great measure the solution of that problem, for the matter of supply is more important than the question of system. Engineers have racked their brains and hoarsed their throats in arguing the merits or demerits of single and poly-phase and high and low tension direct currents, but I tell you

that neither one of these questions is so important as the question of power supply.

“Every one who looks forward to the future of our country sees a spectre arise. What is it? The failure of our coal and timber supply, and the necessary consequences. With an ever-increasing demand for power, we must then fall back upon water and hydraulic power, but meanwhile we must conserve all we have. Mr. Insull has spoken of the limitation which may be imposed by law upon normal development. You can no more stop the extension of electric lines from one State to another than you can stop the travel on a country road, no more than you can put bounds upon agricultural fields, no more than you can dead-end the rails of a steam railroad. The small power plant must disappear, great power plants, properly located, must be erected and connected together by lines which are absolutely protected. In the end, these connections will be underground, not overhead, for protection against accidents to the public, for the same reason the Bell Telephone Company runs its lines from Boston to New York underground instead of overhead. Now, when that time comes, since the demands of the electrified railways will be so small in comparison with the aggregate diversified demands upon power plants, the steam railroad man no longer can say: ‘Reliability cannot be had except under our supervision and control; economical production of power cannot be had except under our management.’ Then they must acknowledge, as it is typified in Chicago, and here and elsewhere throughout the country, that the central station can often supply to a steam railroad power for their purposes in whatever needed quantity with greater reliability and at less cost than the railroad can create it for itself.

“So in time we will have electric railways upon our trunk lines, but it is to you we must look rather than to the disputants as to system. The natural power lines are the rights of way of the railroads themselves.

“I was asked if I had any prophecy to make to-night. I have, and I do not hesitate to make one. Electricity is going to also help the operation of our trunk lines in a somewhat different way. In the United States there are not less than four hundred and fifty thousand to five hundred thousand miles of single-track trunk line operation, and over those are propelled millions of tons of freight and millions of passengers under the control of great

power units, governed by intelligent engineers, backed by efficient braking systems. In front of every one of those engineers is a signboard at every block which says in effect: 'Keep off the grass because it is fresh,' or 'Here is danger.' It is called a signal. On four-fifths of the railroads of the United States it is manually operated, but on the other one-fifth it is set and cleared by the trains as they pass. Every now and then a horrible accident occurs. Why? Because, according to the reports of the Interstate Commerce Commission, there is no reliable connection between that signboard and the man who runs the train. Now I will make this prediction: That long before our main railroads are operated by electricity we will materially increase their safety of operation by tying the signboard and the engineer on the locomotive together electrically, so that the man, who, whether from failing eyesight, adverse weather conditions, momentary inattention, or whatnot, loses for a moment a knowledge of the conditions in front of him, the human freight behind him will not go pellmell into a collision, for the track conditions will be signalled into the train, and it will be braked and stopped in case the engineer fails to exercise the attention which is his duty. That is the prophecy.

"Just a final word: We are not all of us engineers, and are not all commercial men, but there is at least one thing we can be proud of: we belong to that industrial profession which has done more for the safety and for the comfort of the world than all which preceded it, which represents typical American progress, which represents modern industry, and conveys the hope of the future to our posterity.

"Gentlemen, I thank you."

CORRESPONDENCE.

RAVENNA, OHIO, May 29, 1914.

DEAR DR. OWENS:

Yours of the 25th inst., inviting me, on behalf of the National Electric Light Association and The Franklin Institute, to be present at a celebration of the Thirtieth Anniversary of the 1884 Electrical Exhibition of The Franklin Institute and the National Conference of Electricians of the same year, held under its auspices, is at hand. I regret to say that illness in my family, together with a disinclination to make a long journey at this time of the

year, which is doubtless to be charged to "advancing years," compels me to decline the very kind and very tempting invitation, which I do most reluctantly. I am sure the occasion will be of great interest to those who are present, and especially to the rapidly dwindling group of "old-timers" who were on the "skirmish line" a third of a century ago, when, as we were accustomed to hear and say *ad nauseum*, "electricity was in its infancy."

Thinking that there may be something of a historical exhibit in connection with the proposed celebration, and not being able to go myself (though I would be, if present, only an insignificant item in such an exhibit), I am sending you by Adams Express to-day a document which I believe will be of interest to all electricians, whether of the young or the old generation. It has no direct connection with the Exhibition or Conference whose anniversary is to be celebrated, but with the International Congress of a few years later, which was itself, in large measure, an outgrowth of the 1884 gathering. As the original and first record of the definitions of the fundamental units of electrical measurement unanimously adopted by the International Electrical Congress of 1893, and, within a year, enacted into law by the Congress of the United States, thus furnishing a basis on which a business involving many hundreds of millions of dollars has been successfully developed during the last quarter of a century, it is, I think, well worthy of preservation in the archives of some institution like The Franklin Institute or, possibly, the American Society of Electric Engineers. Its history is as follows:

On the afternoon of August 23, 1893, the "Chamber of Delegates" of the International Electrical Congress in session at Chicago began the serious consideration of the definitions of the ohm, ampère, and volt.

Speaking for the American delegates in the Chamber, I had submitted a draft of these definitions upon which the Americans were agreed. There was a long and by no means harmonious debate upon this draft, in which it received the approval of the English delegates but it was opposed in certain particulars by the representatives of Germany and France.

The discussion was not free from a tendency towards national prejudices and animosities, and at one time threatened to interfere with the working of the Chamber to such an extent that it might fail in the accomplishment of the object for which its delegates had assembled from all of the principal nations of the world.

At a late hour it was agreed to refer the whole matter to a representative committee including delegates from England, France, Germany, and the United States, which committee was to report to the Chamber at its next sitting on the following afternoon. This committee, as chosen, consisted of Messrs. Von Helmholtz for Germany, Ayrton for England, Mascart for France, and Mendenhall for the United States, together with the President of the Chamber of Delegates, Professor Rowland, as *ex-officio* member. Late that night, in my room at the hotel, having in mind the criticisms and objections that had developed in the prolonged discussion of the afternoon, I made another draft with pencil on the leaves of a "pad" or tablet of yellow paper that happened to be at hand. In its preparation I tried to avoid both the Scylla and Charybdis upon which wreck had been threatened, and when I submitted my memorandum to the other

As a unit of resistance the International Ohm, which is based upon the Ohm equal to 10^9 units of resistance of the C. G. S. - System of Electro-magnetic Units and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14.4521 grammes in mass of a constant cross section area and of a length of 106.3 Centimetres.

As a unit of current²
 the International Ampere
 which is one tenth of the
 unit of current of the C. G. S.
 system of Electro-magnetic units.
 and which is represented
 sufficiently well for practical
 use by the unvarying current
 which when passed through
 a solution of nitrate of silver
 in water in accordance with
 accompanying specification
 deposits silver at the rate
 of 0.001118 of a gramme
 per second.

3

As a unit of Electro motive
 force the International volt
 is the electromotive force that
 which steadily applied to
 a conductor whose resistance
 is one ^{International} ohm will produce
 a current of one ^{International} ampere,
 and which is represented sufficiently
 well for practical use by $\frac{1000}{1434}$
 of the Electro-motive force between
 the poles or electrodes of the
 voltaic cell known as Clark's
 Cell at a temperature of 15° -
 and prepared in the manner
 described in the accompanying

Specifications

E. Mascart & N. Holmboe

H. N. Rowland

W. R. Ayrton
 T. C. Mendenhall

members of the committee at its meeting on the following morning it was found to require only two or three slight verbal alterations to meet with the approval of all. Where these changes were made may easily be seen at the present time. Just as the committee was about to adjourn it occurred to me that it might be well to insure against possible subsequent change of opinion by having the memorandum signed by all of the members, and a suggestion to that end was cheerfully accepted. A "clean copy" was submitted to the Chamber as the committee's report on the afternoon of August 24th, and after very little discussion was unanimously adopted by that body.

The definitions of the three fundamental units thus adopted, together with other units subsequently approved by the Chamber, were officially accepted by the Superintendent of Weights and Measures at Washington, and, with the approval of the Secretary of the Treasury, were promulgated in Bulletin No. 30 of the U. S. Coast and Geodetic Survey, of which bureau the office of Weights and Measures was at that time a "Division." This immediately affected all government contracts in which electrical measures were involved, but an act of Congress was necessary to make the use of the units compulsory throughout the country. With the advice and assistance of the Chairman of the Committee on Coinage, Weights and Measures of the House of Representatives, the Hon. Charles W. Stone of Pennsylvania (who exhibited a most active and intelligent interest not only in this but in all the legislation affecting weights and measures), I drew the bill which was enacted into law and received the approval of the President on July 12, 1894. This law was proclaimed in Bulletin No. 31 of the U. S. Coast and Geodetic Survey, a copy of which I enclose herewith.

You will note that the law is almost word for word a copy of the memorandum which I am sending you—a few verbal changes having been made, mostly, as I remember, at the suggestion of Mr. Stone, to shorten the phrases as much as possible without affecting their meaning in any way.

Some time after the ending of the International Congress, finding this rough draft among my papers and recognizing its historical interest, I had it put in a frame for preservation as it is to-day.

For several years I have been the sole survivor of the "signatories" and, as the little document seems to mark the beginning of a very important epoch in the history of the "Electrification of the Universe," I have thought for some time that it ought to be in some place where it would be less liable to loss by "fire or theft" than in my own house, and where it would be more easily accessible to any who might be interested in it. If The Franklin Institute cares to become its custodian for the time being, I will be very glad, and it need not be returned to me at present. What is the best place for it finally will be a subject for future consideration.

I am yours faithfully,

(Signed) T. C. MENDENHALL.

DR. R. B. OWENS,
The Franklin Institute,
Philadelphia, Pa.

THE FRANKLIN INSTITUTE AND THE STATE.*

BY

WALTON CLARK, M.E., D.Sc.,

President of the Institute.

THE Institute's purpose, its reason for being, is, within certain well-defined lines, to render service to the State. When we think of the State in this connection we do not confine ourselves to the borders of the great commonwealth which has given us our charter. Our interest and effort are to advance the knowledge of the mechanic arts; to encourage useful research and invention; to aid the struggling worker and reward the worthy worker in the fields of physical science. If in this effort our vision and our influence reach, as we believe, beyond the confines of the city, the commonwealth, and the republic, and beneficially affect the workers of other continents, we are accomplishing in some measure what the founders of the Institute designed and, in their day, realized. The picturesque expression, "splendid isolation," does not apply to The Franklin Institute. While standing alone, secure of its position, and sufficient to the work laid out for it by its founders, it is yet in close and sympathetic touch with the scientific work of the entire world. Through its publication, the JOURNAL, and through the periodic publications of other scientific and governmental bodies of the world, in number over 1500, there is a constant interchange of scientific information on the subjects with which the Institute has to do; and the many stories of invention, discovery, and development that have found their first expression within the walls of the Institute are spread by it as speedily as may be throughout the civilized world.

The Institute is local only to the extent that its habitat is in Philadelphia and the majority of its officers and supporters have been Pennsylvanians. It is cosmopolitan in the range of its interests, its sympathies, and its influence. The scientific world recognizes that for this notable institution, and for the great work it has done for the world in the broad field of science, the citizen of Philadelphia and of the State of Pennsylvania are mainly

* Remarks of Dr. Clark at a joint meeting of scientific and engineering societies of Philadelphia held on the evening of Friday, May 15, 1914.

responsible. Largely because of this work Philadelphia is regarded as in science the leading American city.

The Franklin Institute has to do with the mechanic arts. Does that suggest to any man that we have to do alone with material things?—that the delights of imagination and the glory of an understanding spirit are outside the field of labor of them whom, for the general good, we strive to aid? Believe it not. Let your mental vision range the centuries of invention. Think of Archimedes and DeVinci; of Lippershey and Galileo; of Papin and Watt; of Stevenson and Baldwin; of Daguerre; of Franklin and Faraday; of Morse; of Lavoister and Dalton; of Fulton and Gutenberg and Hoe, and of the hundreds of other discoveries and inventors, self-denying and uplifted servants of their fellow-men, now dead, and of the other hundreds, happily yet living; think of these and believe it not. The tools wherewith have wrought these great workers in Nature's laboratory are of the mind. The application is to the amelioration of man's condition, the broadening of man's understanding, and the extension of man's vision, the refining of man's life and manners—in fewer words, the increasing of man's chance for happiness, through the better adaptation to his use of the substance of the world wherein his Creator has placed him.

To aid in this work, through aiding the worker, The Franklin Institute for the Promotion of the Mechanic Arts was founded. The composition of its membership, provided in its charter and by-laws, evidences the democratic ideals of its founders,—ideals given concrete expression in an Institute in full sympathy with the spirit of American institutions. In the language of the semi-centennial address of President Dr. Coleman Sellers, "It is a Democratic learned society." Our membership is open to any well-behaved man or woman. No honest seeker after truth is too humble of birth, or station, or fortune, or attainments to enter and advantage from our work. No man of science is too exalted in rank to accept an invitation to present his facts and theories in the forum of our hall and our journal. You who follow our work know the truth of these statements; and all men must realize how perfectly adapted is an association so organized to serve the individual and State, and that this organization explains the origin of our vitality and its persistence unimpaired to this day, the beginning of the fourth generation.

The Institute offers fruits in evidence that during this long life it has justified the wisdom of its founders, and of its continuing claim to be an institution of utility to the State.

For ninety years Franklin Institute has maintained a school of instruction in the mechanic arts, from which have gone out thousands of young men, and some young women, to a greater usefulness and to greater opportunity and happiness, because of the education and inspiration had at this school. This education has been a factor of importance in the industrial prosperity of the city of Philadelphia; while the school in which it has been had has served as a pioneer and model in the field of vocational training of the young during their earlier years of actual money-earning employment. We are proud of the character of men whom we graduate—a character that supports them through three or more years of work by day and study by night; we are proud of the evidence their subsequent lives have given of the thoroughness and value of our training, and we are very proud of their loyalty. I do not need to tell this to this audience, but I record it here, that it may come to the knowledge of others who are not so familiar with the work of the Institute, and who, perchance, may read these words, if ever they are printed.

During these ninety years the Institute has maintained a lecture course, free to all who would come, and offering opportunity to obtain knowledge of the progress in the mechanic arts at the fountain-head. I am justified in saying “the fountain-head” by the fact that many notable discoveries, inventions, and developments have had their first announcement in the hall of the Institute.

These lectures have been, many of them, by the foremost men in the scientific world, and each of them has been by a man especially qualified to speak on the subject he has presented. Printed in the JOURNAL, these important pronouncements have gone to the scientist, the operator, and the manufacturer throughout the civilized world.

During its earlier years, up to the time of the Civil War, the Institute held yearly exhibitions, which were recognized throughout the country as important and valuable—illustrating to the generation that saw the beginning of the great American industrial development the then state and progress of the mechanic arts. The value of these early exhibitions and of the great later

exhibitions, notably that held on the fiftieth anniversary of the Institute, and the electrical exhibition of 1884, which eclipsed in brilliancy all previous exhibitions of The Franklin Institute, or of any institute, cannot be exaggerated.

The lines of work originated or first described in The Franklin Institute, and now in general use, some under Government direction, are numerous and important. Among them I may mention the Weather Bureau and the Geological Survey.

But it is the continuing work of the Institute that interests me most—the schools and the lectures, of which I have spoken; the meetings of the sections, where gather, through the year, men of all grades of importance in the various industrial arts, to listen to and to discuss lectures delivered by the nation's foremost representatives of progress in these arts; and the work of the Science and Arts Committee, encouraging and rewarding progress, whether in special lines or in the broad, general field of invention and discovery.

Neither Pennsylvania, nor Philadelphia, nor any other political entity, has given to the Institute one dollar or one dollar's worth of securities or of realty. The benefit that the State has had from the Institute's work has been a contribution to the public good by a part of the citizenship—that part whose devotion of money and time has given the Institute its support. The recompense these citizens have received has come from the love of the work and the satisfaction of accomplishment, and it has sufficed. The regret they feel over the neglect of the State to aid in the work has its beginning and its end in the disappointment of the desire to make more useful what is already of service. We who are at the time responsible for the work of The Franklin Institute have no desire to embark in new ventures. The work inaugurated by our predecessors is sufficient in variety and extent for our talents and our time, as we venture to believe it will be found sufficient for the talents and time of our successors. But we have, as they will have, a desire to further serve, by increasing the utility of our laboratories, of our schools, of our libraries, and of our lecture courses, and to extend the work of the Science and Arts Committee. We know not how to better the work of our sections and our committees. We know very well how to increase the value to the State of the service we render. A more commodious building, on a more convenient site, where

more people can use our better disposed library and find room in a larger lecture hall; where the students who now fill our school-rooms will find less crowded space for themselves and for the others who now can find no room; where new laboratories may be to the present-day demand what our present laboratories were to the demands of our industrial yesterday, is the obvious answer to our problem.

Living in the hope of this opportunity for enlarged usefulness, we shall coincidentally satisfy our ambition by an earnest effort to continue the work of the Institute in a manner in some measure worthy of the examples of our founders and of the emulation of our successors.

In all this we find our "line of least resistance." We are privileged that it falls in such "pleasant places." Following it, we are proud to know that we serve the State and honor the memory of Benjamin Franklin—scientist.

Decomposition of Rubber by Micro-organisms. N. L. SÖHN-GEN and J. G. FOL. (*Zentr. Bakt. u. Parasitenk.*, xl, 87.)—Many bacteria and mould fungi will develop on rubber, in presence of sufficient moisture, at the cost of the protein, sugars, and resins; in some cases red, yellow, black, or brown spots are produced, but the mechanical properties of the rubber are not materially affected. Two species of *Actinomyces*, *A. elastica* and *A. fuscus*, usually present in garden soil and canal water, are capable of attacking and assimilating the caoutchouc hydrocarbon. This action is due to the developing organisms, not to a soluble enzyme secreted by them, and hence the rubber should be dried as rapidly as possible to prevent bacterial growth.

Behavior of the Wehnelt Electrode in Different Gases. K. FREDENHAGEN. (*Phys. Zeitschr.*, xv, 19.)—It is found that nitrogen lowers the efficiency while the dependence on temperature continues constant. Oxygen also lowers the efficiency very much, and diminishes the dependence on temperature, especially at higher pressures. Hydrogen increases the effect and suppresses the temperature influences almost completely. It appears, according to the results obtained with nitrogen, that the neutral gases lower the effect. An explanation of the results obtained with oxygen is offered. The failure of the temperature influences with hydrogen is difficult to explain and further research in this direction is necessary. Methane and coal-gas behave in a manner similar to hydrogen, while cyanogen acts like oxygen.

Coal Briquettes. ANON. (*Machinery*, xl, No. 16, 682.)—A total of about 181,859 net tons of coal briquettes were manufactured in 1913, according to a bulletin of the United States Geological Survey. The figures for 1913 show a decrease of 17 per cent. in the tonnage produced, but an increase of $5\frac{1}{2}$ per cent. in value compared with 1912. Seventeen briquetting plants were in operation during the year—eight in the Eastern States, five in the Central States and four on the Pacific coast. Seven used anthracite culm or “fines,” five used bituminous or semi-bituminous coal, two used carbon residue from oil-gas works, and the others used mixed coals. Coal-tar pitch is the principal binder employed, eight plants use it. Five plants used patented binders.

Atomic Structure. J. J. THOMSON. (*Phil. Mag.*, xxvi, 1044.)—In his recent paper the author supposed that the regions within which the electrical forces inside the atom were supposed to be confined were bounded by conical surfaces. Further investigation shows that the period of a corpuscle inside the region would increase with its energy, and the corpuscle would cease to be in unison with the light before it had acquired enough energy to escape from the region of electrical force. If, however, the boundaries were cylindrical, the period would be independent of the kinetic energy of the corpuscle. The latter would then be in resonance with the light until it had acquired enough energy to escape. Assuming cylindrical surfaces, the results of the paper can apply without further modification.

Band Spectrum of Aluminum. A. DE GRAMONT. (*Comptes Rendus*, clvii, 1364.)—Observations were made of the spectra obtained by introducing metallic aluminum and various aluminum compounds into the high-temperature oxy-acetylene flame. In addition to the five bands already known, a sixth was found, more refrangible than the others. The wave lengths of the heads of the secondary bands in this new band, which is much weaker than the other five, are: 4330.5, 4351.7, 4373.6, 4394.4, 4413.3, 4431.0, 4407.6, and 4462.5. All the bands are degraded, like the others, towards the red, and the first head is not the most intense. A large number of minerals investigated exhibited the aluminum band spectrum.

Graphite as a Lubricant. ANON. (*Amer. Mach.*, xl, No. 22, 938.)—Experiments conducted by Prof. F. W. F. Goss led to the conclusion that a combination of graphite and lard oil makes up a lubricating mixture which, when applied to ball-bearings, will accomplish everything which lard and oil will do, and which, at the same time, will give a lower frictional resistance of the bearings and permit a large increase in the load which they can carry. An oil or light kerosene, when mixed with graphite, becomes an effective lubricant for ball-bearings when operated under light or medium pressure.

THE ENGINEER AS A FACTOR IN MODERN PROGRESS.*

BY

ALEX. C. HUMPHREYS, M.E., Sc.D., LL.D.,

President, Stevens Institute of Technology.

Member of the Institute.

IN speaking briefly to this topic which has been assigned to me I am not unmindful of the fact that I am speaking to the members of many societies the membership of which is made up of men of other professions than of my own—engineering.

I have no sympathy with the man who tries to prove that his profession is *the* profession with regard to service to mankind. But I do sympathize with the man who demands for his profession proper recognition in view of its responsibilities and the fidelity and thoroughness with which the members of the profession live up to their responsibilities.

I do not believe that there is a general appreciation of the engineer's part in the world's work; of how his activities permeate practically every branch of the daily round.

When we call attention to details we are able to show that the engineer puts his mark upon nearly everything material which enters into our life. Wherever we see developed power, machinery, manufactures of all kinds, instruments, apparatus—yes, and articles of food—the engineer's work or influence can be found.

This being the case—and I wish I had time to enlarge on this proposition—it means that the engineer has necessarily to accept a heavy responsibility to maintain and increase the efficiency of the world's operations.

I hold that he must carry a heavy responsibility with regard to governmental problems, and particularly so in this country, which is to-day hysterically active in proposing and trying to solve a multitude of problems, the majority of them involving, directly or indirectly, the industrial questions which the engineer should be qualified to solve.

Let me refer to one line among many.

* Read at a joint meeting of the scientific and engineering societies of Philadelphia held Friday, May 15, 1914.

The engineer should be authoritatively employed in the regulation of our public utilities through the public service commissions, as he is now employed in the management of these public utilities.

It is not an adequate defence for the engineer to say that he has not been called by the voters and their representatives to take a place on the commissions except as a subordinate or member of the staff. The engineer must do his full share to convince the public that this work of regulation and control must not be left to the lawyers, and particularly to the lawyer-politicians. I am not reflecting on the lawyers, but I hold that there is room on these commissions for the engineer, the lawyer, the business man, and the members of all the professions, provided the individuals have good common-sense, common honesty, broad education, including practical experience in administration.

I certainly do not claim that an engineer is qualified to serve acceptably on one of these commissions only because he is an engineer. This applies equally, and perhaps more so, to the lawyer and others.

Judge Prouty, formerly chairman of the Interstate Commerce Commission and now head of the U. S. Board to value the railroads, has recently delivered a strong statement to the effect that, while he did not think so in the past, his experience leads him now to think that the engineer is better qualified temperamentally and by training to serve acceptably on these public service commissions than is the lawyer. To show that the engineers must assert themselves in this connection let me say by way of illustration that only to-day I heard the head of one of our greatest universities (a broad-minded and well-equipped man) state that it is generally understood and accepted that the engineer is not qualified to serve in such administrative positions, but his abilities have to be employed in subordinate and advisory capacities.

Unfortunately engineers have themselves given occasion for this opinion through their failure not infrequently to accept responsibility for the business, economic, and administrative features of the problems put before them. Also, the engineers who have been appointed to such positions have sometimes been the incompetents looking for a job. The engineer to place in such a position of grave responsibility should be a man who has made good—a man of constructive criticism, not of destructive criticism.

We of the United States to-day are suffering from the destructive criticism of those who are incompetent to improve the conditions at which they are so ready to rail and to the reform of which they are willing to devote themselves at so much per hour, week, month, or year.

I am sorry to say that I am convinced (for I am not speaking hastily or rashly) that the college man, the professional men of the country, and especially the economists, are particularly to blame for our present conditions—conditions which I fear are to be worse before they are better.

The so-called educated men—meaning the man of school, college, and books—is to blame far more than the less-favored man if he by his ill-considered words leads others astray.

Particularly is this true of the teacher and professor. The State of Wisconsin has been particularly active in reform movements. Undoubtedly not a little good has been accomplished. But under the academic influence of the State University mistakes have been made.

We now read of organized protests by citizens in various parts of the State against the paternal policies of late so much in evidence in that State. This protest is not directed against public service commissions alone.

I quote from resolutions passed at the organization of the Taxpayers' League of Grant County: "We realize that good may be done in certain lines by commissions of *experienced men properly restricted in their powers*, but we condemn the useless multiplication of commissions to supervise and control every public and private act at the expense of the taxpayers of the State; we condemn the great increase in the cost of commission administration and the employment of hordes of useless employees at public expense. . . . The present conditions in the State of Wisconsin require immediate action for the protection of its people in their rights and property."

Things specified in the protest are: "The great mass of freak and useless legislation"; multiplication of laws; long and expensive legislative sessions; "tremendous indebtedness, and handling of State government by professional politicians."

At the bottom of these protests, bearing every evidence of sincere and honest indignation, lie the growing tax burdens, which in Wisconsin, as elsewhere, are pressing upon the people

as never before in this country during times free from war and its immediate effects.

So long as public utilities and other industries are in private hands responsibility is definitely lodged and those accountable for their activities can be reached and held responsible. When the government assumes the functions of proprietorship, the whole relation to the public changes: transactions of all kinds are confused in the record, and the administration develops into the mysterious fetters of officialdom.

In the same paper from which I have abstracted these statements appears an article by President Van Hise, of the Wisconsin University. Certainly President Van Hise cannot be accused of reactionary tendencies. In fact, he has given evidence of being in sympathy with Wisconsin academic radicalism.

In this article Dr. Van Hise calls for a halt. Particularly he declares against the discrimination against "big business" so much in evidence to-day when the farmers are given freedom to be as big as they please in their combinations. This Van Hise calls a "profoundly immoral situation."

I confess that to get such a warning note from the president of the University of Wisconsin is about as encouraging as anything I have heard of late. Now I am ready for other pleasant surprises.

The legislators are now busy in Washington forging additional fetters for big business, which, properly managed and directed, operates for economy and efficiency.

In this connection let us remember that only a few years ago the States of the Union were almost without exception eagerly competing with each other in offering inducements to corporations to come in and do "big business"; now they are competing with the National Government to sandbag the unhappy victims of their previous legislative activities. Mistakes were made in the past, but if "big business" is to be killed, in fairness the politicians who cultivated and prospered through "big business" should be put out of the way also.

Now why do I say all this to this assemblage? One reason is that it is an unusual opportunity to speak to college men of many professions, and this is the day of college men, engineers and those of other professions, to serve their country, provided

they do not assume, as too many college men do, that the college man is all-sufficient in the working-out of reforms.

I do not think I can do better than conclude by reading an editorial from the *New York Times* of yesterday.

“ COLLEGIANS AND CIVICS.

“ In his little address to the Conference on Universities and their Relation to Public Service Mayor Mitchell brought out one point that may well be considered carefully by those responsible for the universities. By some of them, indeed, the study of it should be accompanied by fasting and prayer. He reported that in many cases that had come under his observation college men who had entered the public service temporarily, or with the intention to remain, were lacking in the ability to handle their work practically, getting on with it less satisfactorily than young men with fewer and poorer ‘ advantages ’ than they. One of the objects which he held out for the consideration of the conference was coöperation to enable men who are in attendance at universities to get a practical knowledge of the workings of government that will fit them to take part in it when they enter business life.

“ The suggestion is a pregnant one. In a lamentable degree it is true of the college teaching of civics that the practical side is neglected and undue stress is laid upon the theoretic side. This is not only true, but it is equally so that the theoretic side has too much to do with more or less abstract views as to the reforms that are assumed to be imperative in the organization of our public life. These views relate for the most part to what is called, in the vernacular, not to say the slang, of modern civics the ‘ uplift ’ of society with especial regard to social changes. This pabulum is exceedingly stimulating to young minds, and it is by no means without nutritive value properly administered; but it needs, in order to be safe, to be accompanied by a substantial element of practical instruction. For one thing, it is highly expedient that students who are to be trained to reform existing institutions and methods should have an accurate and as nearly complete knowledge of what they are to try to reform as possible.

“ If we are to correct evils we must know as nearly as we can the nature and cause of these evils. This means that in training young men and young women in civics we should keep them as close as may be to concrete facts, and restrain them from arriving

too soon at general principles and adopting tempting theories which are usually dangerous in the ratio that they are promising. These restraints are needed first by the minds of the young in their own interest, and, second, in the interest of the public. There is a distinct and peculiar risk in permitting, still more in inducing, the young to think that they have a mission for the bettering of the world before they have attained a knowledge of the world. That conception tends strongly to make them conceited, to transfer to their own credit the goodness of their intentions and to blind them to the truth about themselves and those with whom they have to deal. It puts into their minds much that has afterward to be got out by the stern processes of experience, which are often rude and cruel. In the meantime the public which these young enthusiasts are taught to believe they are serving loses a lot of good hard work which might be done if teaching were more properly adjusted to conditions.

Are we then to abandon the instruction in civics in our universities and banish therefrom the discussion of needed reforms? Certainly not. We must, however, recognize the extreme risks in theoretic teaching unless linked with thorough instruction in the concrete. That is more than a corrective or safeguard against erratic speculation. It is a positive preparation for the world of life, and a discipline in the tasks that await the student. Nor is the process a difficult one. It can be aided by the conference that Mayor Mitchell welcomed to the city and is, we understand, a part of its program. The results may well be beneficial to all concerned, for it is in the field of the concrete that the universities, such as that of Wisconsin, have accomplished most. It is a constantly widening field and may well occupy energies that in the past have been too much devoted to the theoretic."

From a long and instructive experience I say Amen! and Amen! to every word of this editorial.

Splitting of Tiles by Frost. C. RAD. (*Tonind. Zeit.*, xxxviii, 649.)—Glazed tiles with strongly porous edges are split by frost, whereas unglazed tiles made of the same clay are not affected. Glazed bricks are more resistant than glazed tiles. This is due to the greater thickness and less exposed situation of the bricks, through which less water is absorbed, whereas thin, flat roofing tiles become fully saturated.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE EMISSIVITY OF METALS AND OXIDES.—I. NICKEL OXIDE (NiO) IN THE RANGE 600 TO 1300° C.¹

G. K. Burgess and P. D. Foote.

THE object of the present investigation has been the determination of the monochromatic (E_λ) and total emissivity (E) of nickel oxide (NiO) in the range 600 to 1300° C. This oxide forms in a tough, smooth layer on the surface of nickel when subjected to high temperatures in air. Two methods were employed for the determination of the emissivity for red light: (*a*) that of microscopic melts, and (*b*) a direct comparison by a spectrophotometer of the intensity of light emitted by the glowing NiO and by a black body at the same temperature.

In the method of microscopic melts, minute specimens of NaCl, Na₂SO₄, and A μ were placed on the oxide, which was electrically heated until these substances melted, as observed with a microscope, and the "apparent" temperatures at the instant of melting were observed with an optical pyrometer. Hence, knowing both the true and apparent temperatures of the oxide, the emissivity may be computed.

In the spectrophotometric method, a nickel strip was folded forming a wedge- or V-shaped cavity and electrically heated until a coat of the oxide was formed. It has been shown by Mendenhall that the radiation from the interior of a V-shaped cavity is "black." The ratio of the intensities of the outside and inside of the wedge properly corrected for temperature gradient through the walls, gives at once the emissivity at any particular wave length and temperature. Determinations by this method agreed with those by the method of microscopic melts.

The monochromatic emissivity was found to increase linearly with increasing wave length from $\lambda = 0.5$ to 0.7μ and decrease linearly with increasing temperature from 700 to 1300° C. For example, at 1160° C., E_λ increases from 0.86₅ at 0.5μ to 0.88₂ at 0.7μ ; and for $\lambda = 0.65\mu$, E_λ decreases from 0.95₈ at 800° C. to 0.84₅ at 1300° C.

* Communicated by the Bureau.

¹ Scientific Papers of the Bureau of Standards.

The total radiation of NiO was investigated by means of 12 radiation pyrometers of the Thwing and Fery types. These instruments were sighted upon the electrically heated oxide. The apparent temperature of the oxide for $E\lambda = 0.65\mu$ was measured by an optical pyrometer and these values corrected to true temperatures by means of the determinations on the monochromatic emissivity. From the apparent temperatures as determined by the radiation pyrometers and the true temperatures, the total emissivity may be computed. E was found to increase with increasing temperature, but the relation is not linear. Temperatures and E have respectively values as follows: 600° , 0.54; 800° , 0.68; 1000° , 0.76; 1200° , 0.85; 1300° , 0.87. Tables and curves are given for correcting the apparent temperatures of NiO, observed with an optical or radiation pyrometer, to true temperatures.

[ABSTRACT.]

THE SPECIFIC HEAT OF COPPER IN THE INTERVAL 0° TO 50° C. WITH A NOTE ON VACUUM JACKETED CALORIMETERS.*

D. R. Harper 3d.

1. A CRITICAL review of all previous determinations of the specific heat of copper is given *in extenso*. For the general reader the essentials of this are condensed into two tables and a short explanatory note. The determinations in the temperature range $0-100^\circ$ are interpreted to indicate that the specific heat of copper (hard-drawn probably excepted) at 50° is between 0.0926 and 0.0931.

2. The general principles of the method employed in this determination are discussed, together with a consideration of the precision necessary in measuring the various quantities. Then follow a full description of the apparatus and the details of making each measurement.

The specimen of copper was a long wire (50 metres), suspended in vacuo and connected as part of an electric circuit. A measured quantity of heat could thus be imparted to it electrically and the temperature rise found by using the specimen

* To appear in the Bulletin of the Bureau of Standards, vol. 11, 1914.

itself as a resistance thermometer. The test specimen was thus its own calorimeter, no other substance being included in the "water equivalent" with the single exception of a few grammes of mica necessary for electrical insulation.

To arrange a large enough amount of copper in a form suitable for the electrical measurements, the wire was coiled into spirals containing about 150 cm. each, and 32 of these, superposed with mica plates between, built up a cylinder about 10 cm. x 10 cm. containing over 2 kilogrammes of copper and possessing an electrical resistance of about 0.2 ohm, sufficient to permit of making the necessary measurements with requisite accuracy.

Potential leads tapped in at a distance from the ends of the wire served to define a portion, the mass of which was the mass of copper involved in the determination. The resistance of this portion was that which was comprehended in the thermometric factor, and the energy supplied to it during the period of heating was the product of the current in the coil by the potential drop between these leads, integrated over the time the heating circuit was closed. This potential drop was measured directly with a potentiometer and the current was measured with the same potentiometer balanced on the drop across a 0.1 ohm resistance standard connected in series in the circuit. The time factor was obtained by automatic chronograph record of the instants when the heating current was switched on and off.

The specimen was heated 4° to 5° in each experiment, the rise in temperature being determined by the change of resistance of the specimen relative to the resistance of a 0.1 ohm manganin resistance standard immersed in an oil bath. The comparison was effected by a potentiometer, sensitive to about one part in five hundred thousand, and the current employed in making the comparison was small enough (about 0.3 ampère) that its heating effect on the specimen (about $0^{\circ}.001$ per minute) could readily be allowed for without appreciable error.

To obtain the factor for the reduction of the increase in resistance to rise of temperature on the international hydrogen scale, the copper thermometer was compared at several temperatures with two standard platinum thermometers in a suitable stirred oil bath comparator.

By suspending the specimen in vacuo, the uncertainties in the cooling correction which occur at atmospheric pressure due to con-

vection were avoided, the magnitude of the correction was decreased, and uncertainty in amount of air to be included in the water-equivalent (a source of error barely appreciable) was avoided. The efficacy of the vacuum jacket in reducing the magnitude of the cooling correction was by no means what was anticipated and is the occasion of an appended note on the subject.

3. Sources of possible error are carefully considered in the separate discussions pertaining to the measurement of each quantity. The precision of these measurements and the magnitudes of the several correction terms are fully indicated by detailed explanation accompanying a sample laboratory record of an experiment.

4. The copper was annealed wire, 99.87 per cent. pure, according to chemical analysis, high degree of purity being likewise indicated by the electrical properties.

5. The results of 27 determinations at temperatures between 15° and 50° possess an average deviation of one part in a thousand from

$0.383_4 + 0.00020(t-25)$ international joules per gramme degree
equivalent to

$0.0917 + 0.000048(t-25)$ calories₂₀ per gramme degree

Hf 4.182 joules equal one 20° calorie.

6. Appended to the paper is a discussion of the use of the vacuum jacket as a means of reducing the cooling correction in calorimetry, the relative magnitudes of the heat transfer due to conduction by air in various stages of rarefaction and by radiation from some of the more commonly used surfaces being compared. The note is intended to indicate the degree of exhaustion profitable to attain for a given set of fixed radiation conditions when thermal insulation by means of a vacuum jacket is planned.

THE VERITAS FIRING RINGS.*

A. V. Bleininger and G. H. Brown.

IN the pottery and other clay industries the heat effect due to the increasing kiln temperature is frequently determined from the shrinkage of unburned clay rings, of uniform composition and

* Technologic Papers of the Bureau of Standards, No. 40.

size, which are placed in different parts of the kiln. The shrinkage is measured by means of a simple calipering device which permits the reading of small differences in diameter. The object of the present work was the correlation of the arbitrary shrinkage number of the gauge with temperature as measured by means of standardized thermo-couples, so that the devices might be coördinated with pyrometer practice.

The work consisted in firing a number of these rings under conditions of constant temperature increase per unit time. Four firings were made with increases in temperature of 50, 25, 16.66 and 12.5° C. per hour. At frequent intervals rings were withdrawn from the kiln and their diameter measured after cooling. The results showing the shrinkage, expressed both in the numbers indicated by the gauge and in fractions of an inch (obtained by micrometer measurement), are given in tables. The temperature at which equal contraction takes place are the higher the more rapid the firing. The differences diminish as the temperature rises. The shrinkages for the two lower firing rates tend to coincide as the heat absorption becomes constant. Porosity determinations were made in connection with the shrinkage measurements and which resulted in curves practically parallel to the linear contraction. The firing rings were found to answer the purpose for which they are intended satisfactorily. A new series of rings, intended for lower temperatures, was found to be unsatisfactory, owing to irregularities in shrinkage.

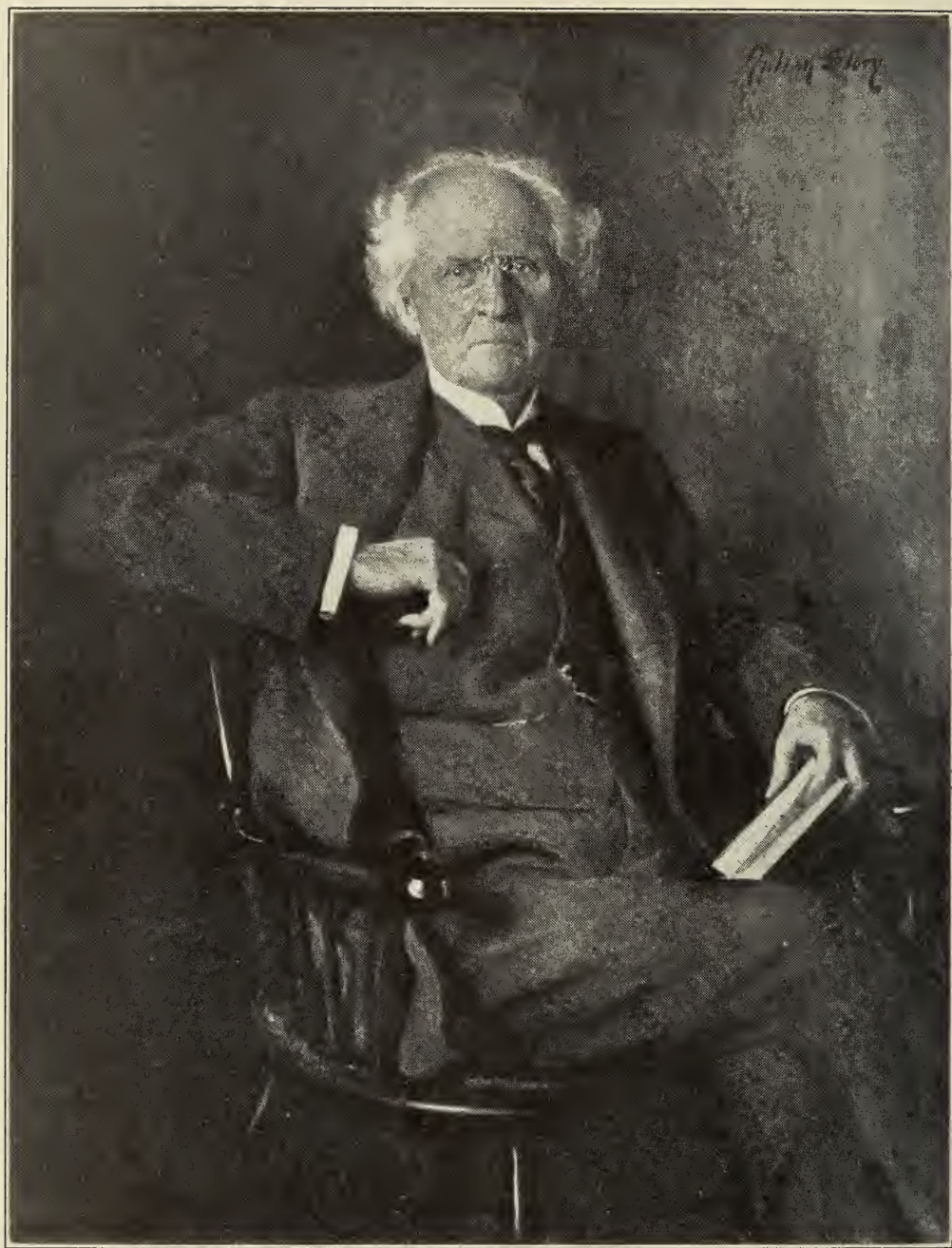
Passenger Locomotives. ANON. (*Machinery*, xx, No. 8, 650.)—It is stated in the *Railway Age Gazette* that a great increase in the capacity of passenger locomotives has been effected by the use of alloy steel, properly heat-treated, for the reciprocating parts. This material considerably reduces the weight of the counter-balances, and thus allows an increased load to be applied to the driving wheels. Hence the boiler can be materially enlarged and the capacity of the locomotive as a whole increased without adding to the total weight.

Mastic Lining for Acid Tanks. ANON. (*Min. and Eng. World*, March 28, 1914.)—Trinidad asphalt mastic has been found to be a satisfactory material for lining concrete tanks which are subjected to the action of sulphuric acid. Many other materials were tried but none were found suitable except the asphalt mastic, which showed no deterioration after a year's test.

Determination of Mineral and Rock Densities at High Temperatures. A. L. DAY, R. B. SOSMAN, and J. C. HOSTETTER. (*Amer. Journ. Sci.*, xxxvii, 1.)—After reviewing existing and somewhat conflicting data on the change of volume on fusion of various rocks, the authors describe apparatus by which the volume of metals and of solid and liquid silicates can be determined from 250° C. to 1600° C. The sensitiveness of the method is from 0.03 to 0.2 per cent. The accuracy varies with the metal used, the temperature, and the size of the sample, but is usually between 0.2 and 0.5 per cent. The fundamental constant is the expansion coefficient of artificial graphite. Volume measurements on quartz up to 1600° C. show a dilatation which increases rapidly as the inversion point of 575° C. is approached. Above this temperature quartz contracts slightly. At about 1300° C. there begins a second and irreversible dilatation due to the formation of cristobalite. Owing to the unequal expansion of the various minerals the rock is fractured, so that the true volume-change over any considerable range cannot be obtained from natural rocks.

Electrolysis of Barium Chloride Solutions with Mercury Cathodes. P. P. FEDOTIEFF. (*Z. Anorg. Chem.*, lxxxvi, 325.)—The Kellner-Solvay method may be applied with good results to the preparation of pure barium oxide from barium chloride solution, a given current yield being obtained with smaller cathode density than with the alkali chlorides, owing to the relative stability of barium amalgam. The amalgam is, however, rapidly decomposed by water at 60° C. in the presence of iron, and a solution which, on cooling, deposits crystals of $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$, is readily prepared. Castner's method is less suitable. An increased cathode density is favorable to a high current yield.

Moving Pictures in the Machine Industry. ANON. (*Amer. Mach.*, xl, No. 16, 676.)—The use of moving pictures in the publicity field of the machine industry is not new, but is becoming extended. One firm, in Hull, England, making oil-mill and other machinery for export, has a "private picture palace" for showing its machinery in operation under various circumstances. This device is found particularly valuable in entertaining foreign customers who want to see how the machinery is employed in actual practice. It is more simple, and really more effective, to show the moving pictures than to show the customers through the mills, even when such a course is possible. It obviates the often unpleasant necessity for asking the permission of customers who had bought the machinery to show prospective customers through their mills. An important variation of the scheme is to send the films abroad, with or without a salesman, for the benefit of customers who might never have an opportunity to see the actual operation of the machinery in other countries.



THOMAS DOLAN

THE FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

NECROLOGY.

Thomas Dolan was born on October 27th, 1834, and died June 12th, 1914. He lived his entire life in Philadelphia and his activities were mainly with those connected with Philadelphia.

As a manufacturer, financier, as President of the United Gas Improvement Company, and as director and adviser of many industries, his many qualities so impressed themselves on these various interests, that he was the leader in each field.

His genial nature, approachable manner and sympathetic interest, at all times, were traits that impressed all who came in contact with him.

He was the pioneer in impressing on those who had reason to use the facilities offered by the various public utility companies, that the desire of these companies was to have their relations on a human basis.

With the great attainments in so many fields possessed by Mr. Dolan, it is somewhat difficult to select the one which seems the most enduring; but all who know of his work will agree that one of the greatest of his achievements was in establishing that community of interest between the user and supplier of so-called Public Utilities, so that to-day the suspicions and ill feelings of the past have changed to a condition of mutual confidence and respect.

Mr. Dolan was identified with many institutions. He was a member of The Franklin Institute for many years, and an earnest, sympathetic believer in its aims and its future, he being one of the subscribers to the Building Fund.

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Denatured Alcohol. ANON. (*Machinery*, xl, No. 16, 682.)—According to a monograph recently issued by the Bureau of Foreign and Domestic Commerce, Germany now uses between 40 and 50 million gallons of denatured alcohol per year, of which over 30 million gallons are sold to the general public for fuel purposes. The importance of this fuel in Germany may be appreciated when it is considered that France uses about 18 million gallons, the United States about 10 million gallons, and the United Kingdom only 4 million gallons. Denatured alcohol is not only gaining in favor for general burning purposes, but a determined effort is being made to find a method of using it as a motor fuel in place of high-priced gasoline.

The American Peat Society will hold its eighth annual meeting in Duluth, Minn., August 20th, 21st, and 22nd.

Important papers on the peat industry, peat lands, and the use of peat for fuel will be presented by numerous investigators and experts from this country and abroad.

The meetings will be held in the rooms of the Commercial Club, where there will also be an exhibition of peat, peat products, and machinery and apparatus for its preparation and development. The program will include excursions and entertainments.

About 4000 vanadium-steel reaction castings were used for the locks of the Panama Canal at Gatun and Miraflores. In planing these the cutting speed was 40 feet per minute; the time required for the lot was $1\frac{1}{2}$ years, working day and night except Sundays. The strain on the planer was so severe that all the gears and racks had to be replaced by steel ones.

CURRENT TOPICS

Recovery of Nitrogen as Ammonia from Coal. J. W. COBB. (*J. Gas Lighting*, cxxvi, 329.)—The experiments of Burgess and Wheeler on the slow distillation of bituminous coal in a vacuum showed that the greatest yield of ammonia per gramme of coal was obtained at about 550°C . Christie noticed that very little ammonia was produced below 500°C . or above 800°C ., and that by slow distillation at 500°C . to 700°C . about twice as much ammonia could be obtained as in the usual coke-oven or gas-retort practice. At 700°C ., when equilibrium is attained, a mixture of nitrogen, hydrogen, and ammonia at atmospheric pressure contains only 0.022 per cent. NH_3 , and a gas consisting of H_2 , 50, N_2 , 5 and NH_3 , 1.2 per cent., if left in contact with the charge in the retort at 800°C . would lose practically all of the ammonia by decomposition. Hence it is necessary to produce the ammonia at the lowest possible temperature and to remove it from the retort as soon as formed. In laboratory experiments at 800°C ., when the gas was removed at once from the hot part of the tube, 22.5 per cent. of the nitrogen in the coal was obtained as ammonia; when the gas passed through a red-hot portion of the tube before exit, 17.2 per cent.; and when the gas passed through red-hot coke, 9.4 per cent. When a current of carbon monoxide, carbon dioxide, or nitrogen was passed over coke at 800°C ., little or no ammonia was obtained from the nitrogen in the coke; with dry hydrogen, 10 per cent. of the nitrogen was liberated as ammonia; and when water vapor, alone or mixed with hydrogen, was used, nearly the whole of the nitrogen was obtained as ammonia. The conditions approximate this in the Mond producer, in which 60–70 per cent. of the nitrogen is recovered. Producer gas or coke-oven gas which has been well scrubbed for the extraction of ammonia is specially suitable for regenerative working on a continuous system without reversals, because it is free from dust and does not choke the narrow conduits.

History of the Zeppelin Airship. MÜLLER. (*Verein zu Beförd. des Gewerbflusses*, Verh. I, 35.)—First are recalled the difficulties encountered by Zeppelin when, in 1894, a German Committee was appointed to consider the military value of his first rigid airship proposals. The present communication is claimed to rectify serious omissions from "Das Werk Zeppelin's," a history compiled in honor of the inventor's 75th birthday. Working on the basis of experience obtained with the 1884–1885 French military airship "La France," defects and limitations were detected in the 1894 Zeppelin ship, and the author gives a connected account of the investigations and cal-

culations which were made; the difficulties encountered owing to the very different shapes of the old and the new crafts; the modifications which were made in the design and dimensions of the Zeppelin ship; and the factors which opposed the realization of conditions seen to be desirable. Numerous formulæ for speed and resistance, etc., are presented, and their applicability and results discussed. The leading dimensions of the "Deutschland" and "La France" are given. Great difficulty was encountered in securing sufficient strength of the hull framework while keeping the total weight sufficiently low; the engines available at that date were relatively heavy and of limited power, hence only low speeds could be attained. Those considerations are clearly set forth which led to the result that very large vessels should be built in order to make possible safe construction while realizing high speed. Lifting power and with it the possibility of strong construction and powerful engines, increases with the third power, whereas air resistance increases only with the second power of the linear dimensions. The difficulty of making the hull strong enough to withstand mooring in the open was realized at an early date. The shape of the hull affects not only air-resistance but also the weight of the framework. Tables are given, showing the length, diameter, capacity, motor horse-power, and speed of Zeppelins I to XIX; LZ-I to 6 inclusive conformed closely to the formula: $\text{Speed (in m./sec.)} = \sqrt[3]{2000 \, n/d^2}$; where n = horse-power and d = diameter; the length of the ships ranging from 128 to 136 metres; their capacity from 11,300 to 15,000 cubic metres; their engine power from 30 to 230 horse-power; and their speeds 7.5 to 13m./sec. The later craft conformed to $v = \sqrt[3]{4000 \, n/d^2}$; their length ranging from 140 to 158 metres; their capacity from 17,500 to 22,465 cubic metres; their engine power from 450 to 510 horse-power, and their speed from 19.3 to 22.2 m./sec. The chief factor which delayed for so long the development of the Zeppelin ships was the weight and limited power of the engines available.

Year	Motor	Horse-power	R. P. M.	Kg. per H. P.	Fuel per H. P. hour
1892 (projected).....	Daimler	11	440	45.0	500 Gm.
1899.....	.....	15	680	25.7	400 Gm.
1905.....	.....	90	1050	4.07	625 Gm.
1907.....	.....	100	1080	3.4	to
1909.....	.....	115	1100	3.2	240 Gm.
1910.....	.....	120	1100	3.2	225 Gm.
1910.....	Maybach	145	1100	3.1	240 Gm.
1913.....	.....	180	1200	2.55	225 Gm.

Radio Research Laboratory for Bureau of Standards. ANON. (*Electr. World*, lxiii, No. 13, 684.)—The Department of Commerce has asked Congress for an appropriation of \$50,000 for the es-

establishment of a wireless-telegraphy research laboratory in connection with the Bureau of Standards at Washington. It is planned to locate the laboratory in the recently completed electrical building of the Bureau of Standards, and the tower for the antennæ will be erected on the east side of the structure. It is proposed to build the tower of masonry in order to preserve the unity of the architecture of the group of buildings.

Artificial Silk Manufacturing Results. ANON. (*Chem. Trade J.*, April 14, 1914.)—The viscose process for the manufacture of artificial silk is making rapid progress among Continental manufacturers, and the financial results of two important concerns that have discarded other processes in favor of the viscose process are sufficient to show that the change has not been made at the expense of the profits. The Fabrique de Soie Artificielle de Tubize, which has hitherto manufactured by the gun-cotton process, is increasing its capital by two million francs to acquire a controlling interest in a new company which will work the viscose system in Belgium. The last report shows a net profit of 1,088,902 francs, and dividends of 25 per cent. on the preference shares and 20 per cent. on the ordinary shares are being paid. The report issued by the Vereinigte Glanzstoff-Fabriken, Elberfeld, probably the largest producers of artificial silk in the world, shows a net profit of 5,743,598 marks, against 3,726,825 marks in the previous year, and a dividend of 34 per cent. is proposed. Up to about two years ago this company worked only the cupro-ammonium process, but it has since adopted the viscose process with good results.

Revision of Road Board Specifications for Tar. ANON. (*J. Gas-Lighting*, cxxv, 807.)—The chief modifications of the earlier specifications are as follows:—*Tar No. 1* (for surface tarring of roads): The requirement that the distillate between 170° C. and 270° C. shall remain clear and free from crystals of naphthalene, etc., when kept at 30° C. for half-an-hour, may be waived in the case of tar supplied direct from gas works, but it is preferable not to use tar containing much naphthalene. The tar should contain from 12 to 21 per cent. of "free carbon" (i.e., residue left after extraction with benzene and carbon bisulphide). *Tar No. 2* (for making tar-macadam and for surface tarring in very hot weather when the road-crust is exceptionally dry): The tar should contain from 12 to 22 per cent. of "free carbon" and may contain up to 25 per cent. by volume of tar (or distillates or pitch therefrom) produced in the manufacture of carburetted water-gas. *Pitch and tar oils.* Prepared pitch from tar distilleries should contain 16 to 28 per cent. and commercial soft pitch 18 to 31 per cent. of "free carbon." The soft pitch and tar oils may contain up to 25 per cent. of products from carburetted water-gas tar.

The Measurement of the Radioactivity of Springs. C. ENGLER, H. SIEVEKING and A. KOENIG. (*Chem. Zeit.*, xxxviii, 425.)—An improved form of the Engler and Sieveking fontactoscope is described, by which more exact measurements of the radioactivity of natural waters may be made. It consists of a vessel of 10 litres capacity, on the neck of which fits a hollow conical stopper, supporting a Wulf quartz-fibre electrometer. Through a hole in the stopper, which can be closed at will by a rubber plug, passes a conducting wire connecting the electroscope with a rod suspended within the large vessel. Before use the normal rate of discharge is determined by shaking in the vessel, for half a minute, one litre of inactive distilled water, charging the electroscope, and observing the fall of potential, which under normal conditions should be between 15 and 30 volts per hour. One litre of the active water is then shaken in the vessel for half a minute, whereby all except about 2 per cent. of the radium emanation is transferred to the air. The fall of potential per hour is again determined, the normal loss deducted, and a correction applied for the solubility of the emanation in the water, and for the Duane effect; *i.e.*, the size and form of the apparatus. From the fall of potential per litre per hour thus calculated, the activity of the water is given by

$$A = \frac{V}{300} \times \frac{C}{3600} \times 1000$$

Mache units, where V = fall of potential and C = capacity of system. The results to be of comparative value must be referred to some definite time from the commencement of the shaking out of the emanation, as the activity, due to the pure emanation, rapidly increases owing to the production of RaA and RaC . In making rapid measurements the readings should be taken two minutes from the commencement of the shaking out, and tables are given to enable such figures to be referred to the zero time; *i.e.*, the activity of the pure emanation.

Gardner's Gyroscope. ANON. (*Engineering*, xcvii, 229.)—Describes the specially free running gyroscope for use in steering a torpedo. It may be spun by a jet of compressed air directed on to buckets in its periphery. With an initial speed of 4000 revolutions per minute the total run may last about 35 minutes, the diameter is 3 inches and the mass 2 pounds.

Flameway in Boilers. ANON. (*Amer. Mach.*, xl, No. 8, 759.)—The aim of boiler designers is to obtain the greatest number of pounds of steam to each pound of metal in the boiler. Various studies and experiments have clearly indicated the advantage of the use of a longer flameway between the fuel bed and the end of the tubes, giving an opportunity of completing the gaseous reaction before the products of combustion enter the flues.

Powerful Röntgen-ray Tube with a Pure Electron Discharge.

W. D. COOLIDGE. (*Phys. Rev.*, 2 Ser. 2, 409.)—A new and powerful Röntgen-ray tube is herein described in detail. It differs in principle from the ordinary type in that the discharge current is purely thermionic in character. Both the tube and the electrodes are as thoroughly freed from gas as possible, and all the characteristics seem to indicate that positive ions play no appreciable rôle. The pressure is as low as it has been possible to make it; *i.e.*, not more than a few hundredths of a micron (*i.e.*, a few hundred-thousandths of a mm.), instead of as in the ordinary tube a few microns (thousandths of a mm.). The cathode consists of a body which can be electrically heated (such as a tungsten or tantalum filament) and, suitably located with reference to this portion, an electrically conducting ring or cylinder, consisting preferably of molybdenum or tungsten or other refractory metal. The ring or cylinder is connected either to the heated portion of the cathode or to an external source of current, by means of which its potential may be brought to any desired value with respect to the heated portion. The heated portion of the cathode serves as the source of electrons while the ring or cylinder assists in so shaping the electrical field in the neighborhood of the cathode that the desired degree of focussing of the cathode-ray stream upon the target shall result. The anti-cathode, or target, functions at the same time as an anode. The tube allows current to pass in only one direction and can therefore be operated from either direct or alternating current. The intensity and the penetrating power of the Röntgen rays produced are both under the complete control of the operator, and each can be instantly increased or decreased independently of the other. The tube in operation shows no fluorescence of the glass and no local heating of the anterior hemisphere. The starting and running voltage are the same.

Explosion of Acetylene from Calcium Cyanamide in Trieste

Harbor. G. MORPURGO. (*Mitt. K. K. T. Techn. Versuchsanst.*, iii, 60.)—This is a report on a violent explosion which occurred last January on a ship having on board 600 sacks of calcium cyanamide. Eight samples of the calcium cyanamide yielded on treatment with water, acetylene corresponding to from 1.28 to 9.35 per cent. of calcium carbide. The hold in which the sacks were stored was only half-full and was not ventilated, and the explosion was evidently due to the liberation of acetylene from the carbide present in the calcium cyanamide by the action of moisture. It has been ordered that in future, calcium cyanamide must always be packed in iron drums for transportation. The author has found that if jute sacks which have been impregnated with rosin solution be used and filled while still damp, the rosin solution combines with the calcium cyanamide with which it comes in contact, and forms a perfectly water-tight coating.

Embrittling of Iron by Sodium Hydroxide. J. H. ANDREW. (*Trans. Faraday Soc.*, March, 1914.)—Wrought iron corrodes slowly, becomes highly crystalline, and eventually brittle by immersion in a concentrated aqueous solution of sodium hydroxide at 100° C. for several months. The corrosion is attributed to electrolytic action between the two phases, crystalline and amorphous, of which the metal is constituted, iron going into solution at the anode (forming sodium ferrite), hydrogen being liberated at the cathode. Part of the hydrogen is occluded by the metal, being first absorbed by the amorphous constituent, thereby forcing the crystals apart, and ultimately causing the iron to become crystalline and brittle. The brittleness decreases with time, an equilibrium being finally established between the metal and the gas, and is due rather to the molecular rearrangement induced by mere occlusion or evolution of hydrogen than to the mere presence of the latter in solution. The potential difference between the amorphous and crystalline phases and hence the rate of corrosion decrease as the latter phase becomes hydrogenized, the passivity of iron produced by immersion in caustic soda being due to this cause. Similar results were obtained with electro-deposited iron, but steel containing 0.5 per cent. carbon was much less affected by sodium hydroxide solution. The recrystallization of electro-deposited iron upon cooling through the Ar_3 point is also considered to be due to the evolution of hydrogen.

Ignition of Gaseous Mixtures by the Electric Discharge. H. F. COWARD, C. COOPER, and J. JACOBS. (*Chem. Soc. Trans.*, cv, 1069.)—The inflammability of various gaseous mixtures was compared by determining the lowest pressures at which the mixtures could be ignited with a given sparking arrangement. Mixtures of oxygen and hydrogen were more inflammable as the proportion of oxygen was increased up to 70 per cent. Electrolytic gas at a pressure somewhat too low for ignition became inflammable by adding, without change of volume, either oxygen, hydrogen, nitrogen, carbon dioxide, or argon. Experiments were also made with mixtures of oxygen with carbon monoxide, cyanogen, methane, and ethylene respectively, and with various diluents in each case. Two important factors governing the ignition were the thermal conductivity of the mixture and the energy degraded when the spark was passed; in the case of the mixtures of moist carbon monoxide with oxygen and diluents, a third important factor was the "activation" of oxygen by the discharge.



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STABILITY OF AËROPLANES.*

BY

ORVILLE WRIGHT, B.S., LL.D.,

Member of the Institute.

THE subject of "Stability of Aëroplanes" is too broad to permit of a discussion of all of its phases in one evening. I shall, therefore, confine myself more particularly to a few phases of the fore-and-aft or longitudinal equilibrium. Although in learning to fly the beginner finds most difficulty in mastering the lateral control, it is his lack of knowledge of certain features of the fore-and-aft equilibrium that leads to most of the serious accidents. These accidents are the more difficult to avoid because they are due to subtle causes which the flyer does not at the time perceive.

A flying machine must be balanced in three directions: about an axis fore and aft in its line of motion, about an axis extending in a lateral direction from tip to tip of the wings, and about a vertical axis. The balance about the lateral axis is referred to as fore-and-aft or longitudinal equilibrium; that about the fore-and-aft axis as lateral equilibrium, and that about the vertical axis is generally referred to as steering, although its most important function is that of lateral equilibrium.

* Presented at the stated meeting of the Institute held Wednesday, May 20, 1914, when Dr. Wright received the Institute's Elliott Cresson Medal in recognition of the epoch-making work accomplished by him in establishing on a practical basis the science and art of aviation.

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If the centre of support of an *aëroplane* surface would remain fixed at one point, as is practically the case in marine vessels and in balloons and air-ships, equilibrium would be a simple matter. But the location of the centre of pressure on an *aëroplane* surface changes with every change in the angle at which the air strikes the surface. At an angle of 90 degrees it is located approximately at the centre of the surface. As the angle becomes less, the centre of pressure moves forward. On plane surfaces it continues to move forward as the angle decreases until it finally reaches the front edge. But on cambered surfaces the movement is not continuous. After a certain critical angle of incidence is reached, which angle depends upon the particular form of the surface, the centre of pressure moves backward with further decrease in angle until it arrives very close to the rear edge. At angles ordinarily used in flying, angles of 3° to 12° , the travel of the centre of pressure is in this retrograde movement and is located, according to the angle of incidence, at points between 30 per cent. and 50 per cent. back of the front edge of the surface. The location of the centre of pressure on any given surface is definitely fixed by the angle of incidence at which the surface is exposed to the air.

The placing of the centre of gravity of the machine below its centre of support appears, at first glance, to be a solution of the problem of equilibrium. This is the method used in maintaining equilibrium in marine vessels and in balloons and air-ships, but in flying machines it has the opposite of the desired effect. If a flying machine consisting of a supporting surface, without elevator or other means of balancing, were descending vertically as a parachute, the centre of gravity vertically beneath the centre of support would maintain its equilibrium. But as soon as the machine begins to move forward the centre of pressure, instead of remaining at the centre of the surface, as was the case when descending vertically, moves toward that edge of the surface which is in advance. The centre of gravity being located at the centre of the surface and the centre of pressure in advance of the centre of the surface, a turning moment is created which tends to lift the front of the machine, thus exposing the surfaces at a larger angle of incidence and at the same time to a greater resistance to forward movement. The momentum of the machine, acting through its centre of gravity below

the centre of forward resistance, combines with the forward centre of pressure in causing the surface to be rotated about its lateral axis. The machine will take an upward course until it finally comes to a standstill. The rear edge of the surface will now be below that of the front edge and the machine will begin to slide backward. The centre of pressure immediately reverses and travels towards the rear edge of the surface, which now in the backward movement has become the front edge. The centre of gravity again being back of the centre of pressure, the advancing edge of the surface will be lifted as before, and the pendulum effect of the low weight will be repeated. A flying machine with a low centre of gravity, without rudders or other means to maintain its equilibrium, will oscillate back and forth in this manner until it finally falls to the ground.

It will have been observed from the foregoing that the equilibrium in the horizontal plane was disturbed by two turning moments acting about the lateral horizontal axis of the machine; one produced by the force of gravity and the lift of the surface acting in different vertical lines, and the other by the centre of momentum and the centre of resistance acting in different horizontal lines.

It is evident that a low centre of gravity is a disturbing instead of a correcting agent. The ideal form of flying machine would be one in which the centre of gravity lies in the line of the centre of resistance to forward movement and in the line of thrust. In practice this is not always feasible. Flying machines must be built to land safely as well as to fly. A high centre of gravity tends to cause a machine to roll over in landing. A compromise is therefore adopted. The centre of gravity is kept high enough to be but a slight disturbing factor in flight and at the same time not so high as to interfere in making safe landings.

The three forces acting on an aëroplane in the direction of its line of motion are the thrust of the propellers, the momentum or inertia of its weight, and the resistance of the machine to forward travel. If travelling in any other than a horizontal course, a component of gravity in the line of motion will have to be reckoned with. When these forces are exerted in the same line, with the centres of thrust and momentum acting in the opposite direction to that of the centre of resistance, a variation in the quantity of any one, or of all, of these forces will not in

itself have a disturbing effect on the equilibrium about the lateral horizontal axis. But these forces in the ordinary flying machine do not act in the same line. Usually the centre of thrust is high in order to give proper clearance between the propellers and the ground; the centre of gravity is low to enable the machine to land without danger of being overturned; and the centre of resistance is usually between the centres of thrust and gravity. When a flying machine is travelling at uniform speed the propelling forces exactly equal the resisting forces. In case the thrust of the propellers is diminished by throttling the motor, the momentum of the machine acting below the centre of resistance carries the lower part of the machine along faster than the upper part, and the surfaces thus will be turned upward, producing a greater angle and a greater resistance. The same effect is produced if the machine be suddenly struck by a gust of wind of higher velocity from in front. The thrust of its propellers will be temporarily slightly decreased, the resistance due to the greater wind pressure will be increased, and the momentum of the machine (the centre of gravity being low) will in this case also turn the surfaces upward to a larger angle. While these variations in the forces acting in the horizontal line have of themselves a certain amount of disturbing effect, yet it is from the changes of incidence which they introduce that one encounters the greatest difficulty in maintaining equilibrium.

The two principal methods used in preserving fore-and-aft equilibrium have been, first, the shifting of weight so as to keep the centre of gravity in line with the changing centre of lift; and, second, the utilization of auxiliary surfaces, known as elevators, to preserve the position of the centre of pressure in line with a fixed centre of gravity. The first method has been found impracticable on account of the impossibility of shifting large weights quickly enough. The second method is that used in most of the flying machines of to-day.

Flying machines of this latter type should have their auxiliary surfaces located as far as possible from the main bearing planes, because the greater the distance the greater is the leverage and consequently the smaller the amount of surface required. The auxiliary surfaces are usually placed either in front or in the rear of the main supporting surfaces, since they act with greater efficiency in these positions than when placed above or below.

With a view to high efficiency, no part of either the main surfaces or the auxiliary surfaces should be exposed on their upper sides in a way to create downward pressures. One pound of air pressure exerted downward costs as much in propelling power as two pounds of downward pressure produced by actual weight carried. This is due to the fact that the total pressure on an *aéroplane* is not vertical, but approximately normal to the plane of the surface. This pressure may be resolved into two forces, one acting in a line parallel with the direction of travel, and the other at right angles to the line of travel. One is termed "lift" and the other "drift." With a given *aéroplane* surface, the drift and lift for any given angle of incidence always bear a definite ratio to one another. This ratio varies from 1 to 12 to 1 to 1, according to the angle of incidence and the shape of the surface. On an average it is about 1 to 6, so that the thrust required of the propeller in the ordinary flying machine is approximately one-sixth of the weight carried. When travelling on a horizontal course the lift is vertical and is exactly equal to the total weight of the machine and load. This load may be real weight, or it may be partly real weight and partly downward pressures exerted on parts of the surfaces. For every pound of weight carried, a thrust of approximately one-sixth pound is required. If, however, instead of real weight a downward air pressure is exerted on some part of the machine, this downward pressure must be overcome by an equal upward pressure on some other part of the machine, to prevent the machine from descending. In this case the horizontal component of the one pound downward pressure will be about one-sixth pound, and the horizontal component of the compensating upward pressure also will be about one-sixth pound, making a total of one-third pound required in thrust from the propellers, as compared with one-sixth pound thrust required by one pound actual weight carried. It is, therefore, evident that the use of downward air pressures in maintaining equilibrium is exceedingly wasteful, and, as far as possible, should be avoided. In other words, when the equilibrium of an *aéroplane* has been disturbed, instead of using a downward air pressure to depress the elevated side an upward pressure should be utilized to elevate the low side. The cost in power is twice as great in one case as in the other.

The dynamically less efficient system of downward air pres-

tures is used to some extent, however, on account of its adaptability in producing more or less inherently stable *aéroplanes*. An inherently stable *aéroplane* may be described as one in which equilibrium is maintained by an arrangement of surfaces, so that when a current of air strikes one part of the machine, creating a pressure that would tend to disturb the equilibrium, the same current striking another part creates a balancing pressure in the opposite direction. This compensating or correcting pressure is secured without the mechanical movement of any part of the machine.

The first to propose the use of this system for the fore-and-aft control of *aéroplanes* was Penaud, a young French student, who did much experimenting with model *aéroplanes* in the 70's of the last century. His system is used only to a slight extent in the motor-driven *aéroplanes* of to-day, on account of its wastefulness of power and on account of its restriction of the manœuvring qualities of the machine.

Penaud's system consists of a main bearing surface and a horizontal auxiliary surface in the rear fixed at a negative angle in relation to the main surface. The centre of gravity is placed in front of the centre of the main surface. This produces a tendency to incline the machine downward in front, and to cause it to descend. In descending the *aéroplane* gains speed. The fixed surface in the rear, set at a negative angle, receives an increased pressure on its upper side as the speed increases. This downward pressure causes the rear of the machine to be depressed till the machine takes an upward course. The speed is lost in the upward course, the downward pressure on the tail is relieved, and the forward centre of gravity turns the course again downward. While the inherently stable system will control a machine to some extent, it depends so much on variation in course and speed as to render it inadequate to meet fully the demands of a practical flying machine.

In order to secure greater dynamic efficiency and greater manœuvring ability, auxiliary surfaces mechanically operable are used in present flying machines instead of the practically fixed surfaces of the inherently stable type. These machines possess the means of quickly recovering balance without changing the direction of travel and of manœuvring with greater dexterity when required. On the other hand, they depend to a greater

extent upon the skill of the operator in keeping the equilibrium. It may be taken as a rule that the greater the dynamic efficiency of the machine and the greater its possibilities in manœuvring, the greater the knowledge and skill required of the operator.

If the operator of a flying machine were able to "feel" exactly the angle at which his aëroplane meets the air, ninety per cent. at least of all aëroplane accidents would be eliminated. It has been the lack of this ability that has resulted in so large a toll of human lives. Instruments have been produced which indicate closely the angle of incidence at which the machine is flying, but they are not in general use. Nor does the average flyer realize how exceedingly dangerous it is to be ignorant of this angle. Most of the flyers are aware that "stalling" is dangerous, but do not know when they really are "stalling."

A flying machine is in great danger when it is flying at its angle of maximum lift. A change either to a smaller or a larger angle results in a lesser lift. There is this important difference, however, whether the angle be increased or decreased. While a smaller angle gives less lift, it also has less drift resistance, so that the machine is permitted to gain speed. On the other hand, the larger angle gives not only less lift but encounters a greater resistance, which causes the speed of the machine to be rapidly checked, so that there is a double loss of lift—that due to angle and that due to a lesser speed.

The maximum lift is obtained in most flying machines at some angle between 15° and 20° . If the machine be gliding from a height with the power of the motor throttled or entirely turned off, and the operator attempt to turn it to a level course, the speed of the machine will soon be reduced to the lowest at which it can support its load. If now this level course be held for even only a second or two, the speed and the lift will be so diminished that the machine will begin to fall rapidly.

The centre of pressure on a cambered aëroplane surface at angles greater than 12° to 15° travels backward with increase of angle of incidence, so that when a machine approaches the "stalled" angles the main bearing surfaces are generally carrying practically all of the weight and the elevator practically none at all. Under these conditions the main surfaces fall more rapidly than does the rear elevator. The machine noses downward and plunges at an exceedingly steep angle toward the earth. This

plunge would tend to bring the machine back to normal speed quickly were the machine flying at its usual angle of incidence. But at the large angles of incidence the drift is a large part of the total pressure on the surfaces, so that, although plunging steeply downward, speed is recovered but slowly. The more the operator tries to check the downward plunge by turning the elevator, the greater becomes the angle of incidence, and the greater the forward resistance. At ordinary stalled angles the machine must descend at an angle of about 25° with reference to the horizontal in order to maintain its speed. If the speed be already below that necessary for support, a steeper angle of descent will be required, and considerable time may be consumed before supporting speed can be recovered. During all this time the machine is plunging downward. If the plunge begins at a height of less than two or three hundred feet, the machine is likely to strike the ground before the speed necessary to recover control is acquired.

The danger from "stalling" comes in the operator attempting to check the machine's downward plunge by turning the main bearing surfaces to still larger angles of incidence, instead of pointing the machine downward, at a smaller angle of incidence, so that the speed can be recovered more quickly. It is safe to say that fully 90 per cent. of the fatal accidents in flying are due to this cause. Most of the serious ones occur when, after long glides from considerable heights, with the power of the motor reduced, an attempt is made to bring the machine to a more level course several hundred feet in the air. The machine quickly loses its speed and becomes "stalled." All of us who have seen the novice make a "pancake" landing have seen the beginning of a case of "stalling" which might have been fatal had it taken place at a height of one or two hundred feet.

The greatest danger in flying comes from misjudging the angle of incidence. If a uniform angle of incidence were maintained, there would be no difficulty in fore-and-aft equilibrium. As has already been stated, for any given surface and any given angle of incidence the position of the centre of pressure is fixed. Under these conditions, if the centre of gravity were located to coincide with the centre of pressure and a uniform angle of incidence maintained, the machine would always be in equilibrium.

It is in accordance with this principle that experiments the

past year have brought about a considerable advance in the development of automatic stability. A small horizontal wind vane is so mounted on the machine as to ride edge-wise to the wind when the machine is flying at the desired angle of incidence. In case the machine varies from the desired angle, the air will strike the vane on either its upper or lower side. The slightest movement of the vane in either direction brings into action a powerful mechanism for operating the controlling surfaces.

If the wind strikes the vane on the under side, as would be the case when the machine takes a larger angle of incidence, the elevator is turned to cause the machine to point downward in front till the normal angle is restored. If the air strike the vane from above, a smaller angle of incidence is indicated, and an opposite action on the elevator is produced. In this system no particular angle of the machine with the horizontal is maintained. It is the angle at which the air strikes the aéroplane surface that is important. If the vane is set at an angle of 5° with the main supporting surfaces, and the machine is travelling on a level course, increasing the power of the motor will cause it to begin taking on more speed. But as the lifting effect of an aéroplane surface is the product of two factors—its speed and its angle of incidence—any increase in speed will produce a greater lift and cause the machine to rise. The machine will now be turned upward, with the surfaces meeting the air at an angle of 5° . On the contrary, if the power of the motor be reduced or entirely turned off, the machine will immediately begin to decrease in speed, requiring a larger angle of incidence for support. But as soon as the angle begins to increase the air will strike the regulating vane on the underside and the elevator will be turned, pointing the machine downward till the component of gravity in the direction of travel becomes sufficient to maintain the normal speed. In this case the planes will be inclined downward with reference to the horizontal. It is evident that a machine controlled by regulating the angle of the machine with reference to the impinging air is not liable to the dangers of “stalling” already described.

Several other methods of maintaining fore-and-aft equilibrium automatically have been proposed. One utilizes the force of gravity acting on a pendulum or a tube of mercury; the other, the gyroscopic force of a rapidly revolving wheel. In both

of these systems the angle of the machine is regulated with reference to the horizontal, or some other determined plane, instead of with the angle of the impinging air.

In the case just referred to, in which the power of the motor was suddenly turned off while travelling on a level course, with these systems, the planes would be maintained at their original angle with the horizontal without any regard to the angle of incidence. The machine would continue forward till, through the loss of momentum, its speed would become so reduced and its angle of incidence so great that it would be exposed to the dangers of diving.

The pendulum and mercury tube have other serious faults which render them useless for regulating fore-and-aft equilibrium. If the machine suddenly meet with a greater resistance to forward travel, either as a result of change in direction or of meeting a stronger gust of wind from in front, and its speed be ever so slightly checked, the pendulum will swing forward and instead of turning the machine downward, so as to maintain the normal speed, will cause the machine to be inclined upward in front and thus further increase its forward resistance.

The pendulum has proved itself an exceedingly useful device, however, in regulating the lateral stability of *aëroplanes*. In this case the effects of momentum and centrifugal force act on the pendulum in the proper direction to produce desired results.

I believe the day is near at hand when the flyer will be almost entirely relieved of the work of maintaining the equilibrium of his machine, and that his attention will be required only to keeping it on its proper course and in bringing it safely in contact with the ground when landing.

Wild Silk from Mexico. ANON. (*Bull. Imp. Inst.*, xii, 45.)—Wild silk is obtainable in large quantities in the States of Vera Cruz and Oaxaca, where the Indians use it for rope-making. The sample examined consisted of a flat, loosely-spun, web-like nest, of 12 inches by 18 inches. The web amounting to 24 per cent. of the whole sample, when separated as far as possible from extraneous matter and degummed by boiling soap solution, yielded a gray to grayish-brown silk of good lustre and strength. It is unlikely that the material could be used commercially, owing to the low yield of degummed silk (about 10 to 15 per cent.) and the difficulties of cleaning and carding.

THE SCREW PROPELLER: WITH SPECIAL REFERENCE TO AËROPLANE PROPULSION.*

BY

W. F. DURAND,

Professor of Mechanical Engineering, Leland Stanford, Jr., University.

(I) INTRODUCTORY.

THE fundamental problem of propulsion is the development of a propulsive force (thrust or pull). This may be viewed in two ways, according as we focus our attention on the medium acted upon (air or water) or on the agent (blade, oar, or float).

Fixing our attention on the medium, we remember that, according to Newton's laws of motion, force is required to accelerate the motion of matter, and to every action there is an equal and opposite reaction. To develop a propulsive thrust it will therefore be sufficient to lay hold of a certain amount of matter and give to it an accelerated motion directed aft, or with a component so directed. This will require the exhibition of a force directed in the line of the acceleration. The resultant reaction, equal and opposite in direction, will be a force acting forward or with a forward component, and hence available as a propulsive thrust.

Thus a Gatling gun firing bullets over the stern of a boat, a boy throwing stones, or a pump throwing water are all ways of producing a propulsive thrust, though differing from those commonly employed.

Again fixing our attention on the agent, we assume a body *B* of some appropriate form (a propeller blade, an oar, or a float) to move relative to the boat or aëroplane through a mobile but resisting medium, such as water or air. We know by the laws of mechanics and still better by common experience that such motion will meet with a resistance manifested as a force acting from the medium to the body and causing a redistribution of the fluid pressure over the surface. This redistribution of surface pressure, constituting as it does a system of elementary forces,

* The substance of two lectures delivered before the students at the U. S. Army Aviation School, San Diego, California, and communicated by Lieut.-Col. Samuel Reber.

will have a single definite resultant R , and this resultant will have a component Q along the line of relative motion, constituting a resistance to such motion and calling for the expenditure of work in order to sustain it.

The total resultant R as noted represents the distributed system of forces acting on the body B . But the body B is in effect a part of the boat. Hence the boat will be acted on by way of the same force R acting along the connection between B and the boat and constituting an external push to which the boat will respond in such manner as may be determined by other conditions. Thus there may be a number of such forces R , as from a number of propeller blades or a number of paddle-wheel floats, and these will have some one final resultant, and this will constitute a propulsive thrust or pull in answer to which the boat will move along the line of such force, ultimately at a speed which will develop a resistance exactly equal and opposite to the propulsive force.

Thus, in brief, the propulsive blade or body is so moved through a resisting medium (such as air or water), and under such geometrical conditions as to form and direction of motion, that the resistance opposed to the motion will give a reaction having a component directed forward, and hence available as a propulsive thrust or pull.

In dealing with practical problems it is necessary to be able to connect up the dimensions and conditions of operation of the propeller with the propulsive force produced. With the first method of consideration this would require, corresponding to any stated size and form of blade and conditions of operation, a knowledge of just how much water or air the propeller lays hold of, and what acceleration is produced in its motion. With the second method of consideration it would require, corresponding to any stated size and form of blade and conditions of operation, a complete and detailed knowledge of the amount and distribution of pressure over the surface of the blade.

Actually, neither of these results can be determined by purely theoretical analysis. This simply means that our knowledge of the laws of hydro or aërodynamics is not sufficient to deduce from the form of the agent (blade or vane) and the conditions of motion either the resulting reaction on the agent or the detailed result on the water or air. We may, however, develop

important relations between these various quantities, thereby laying a foundation for the application of experimental research to the solution of practical problems.

(2) PROPELLER ACTION FROM CONSIDERATION OF RESULTS ON MEDIUM.

Thus for the first method of consideration :

- Let v = velocity of craft forward in f.s.
 u = final velocity of air aft in f.s. = total change in velocity of air.
 w = final velocity of air transversely in f.s.
 mu = velocity of flow of air aft to meet propeller.
 A = disc area in square feet or area of column of air acted on.
 σ = density in pounds per cubic foot.
 T = thrust developed in pounds.
 e = efficiency.

The total velocity of flow of air to the propeller is $v + mu$, and the total mass of air acted on will therefore equal $(v + mu) A \sigma$.

Then by the principles of mechanics we have as follows :

$$T = \frac{(v + mu) A \sigma u}{g} \dots\dots\dots (1)$$

We now recognize four components of the total work as follows :

- (1) The useful work Tv .
- (2) The work carried away by the residual sternward velocity of the water u .
- (3) The work carried away by the residual transverse or rotational velocity of the water w .
- (4) The work carried away by and absorbed in turbulence.

These take values as follows :

Useful work = $Tv = \frac{(v + mu) A \sigma uv}{g} \dots\dots\dots (2)$

Work involved in residual velocity of air u is

$$\frac{(v + mu) A \sigma u^2}{2g} = \frac{Tu}{2}$$

Work involved in residual velocity of air w is

$$\frac{(v + mu) A \sigma w^2}{2g} = \frac{T w^2}{2u}$$

For the present purpose we may assume the work absorbed in turbulence plus the work involved in the rotational velocity w to be related to the energy relative to the residual velocity u by a factor f .

Then the total lost work will be

$$\frac{(1+f)(v+mu)A\sigma u^2}{2g} = \frac{T(1+f)u}{2}$$

Hence efficiency

$$e = \frac{Tv}{Tv + T \frac{(1+f)u}{2}} = \frac{v}{v + \frac{(1+f)u}{2}} \dots\dots\dots (3)$$

or efficiency

$$e = \frac{1}{1 + \left(\frac{(1+f)}{2} \right) \left(\frac{u}{v} \right)} \dots\dots\dots (4)$$

For various values of f and of $\frac{u}{v}$ we have efficiencies as follows:

$\frac{u}{v}$	Values of f							
	.5	1.0	1.5	2.0	2.5	3.5	3.5	4.0
.20	.870	.833	.800	.769	.741	.714	.690	.667
.30	.816	.769	.727	.690	.656	.625	.597	.571
.40	.769	.714	.667	.625	.588	.556	.526	.500
.50	.727	.667	.615	.571	.533	.500	.471	.444
.60	.690	.625	.571	.526	.488	.455	.426	.400
.70	.656	.598	.533	.488	.449	.417	.388	.364
.80	.625	.556	.500	.455	.417	.384	.357	.333
.90	.597	.526	.471	.426	.388	.357	.331	.308
1.00	.571	.500	.444	.400	.364	.333	.308	.286

Table Giving Values of Efficiency.

(3) RELATION OF SPEED, POWER, THRUST.

It is often necessary to use the relations between speed, power, and thrust or pull on the propeller shaft. These may be developed as follows:

Tv = thrust work in f.p.s.

$Tv \div 550$ = thrust horsepower = W

Whence $T = \frac{550 W}{v}$

Again let z = speed in m.h.

Then 1 m.h. = $5280 \div 60$ f.m. = 88 f.m. = 1.47 f.s.

Then $88 z$ = speed in f.m.

and $T = \frac{33000 W}{88 z} = \frac{375 W}{z}$

For $W = 1$ we have table as follows, giving thrust in pounds per *thrust* horsepower at varying speeds in miles per hour :

z	T	z	T
20	18.75	65	5.77
25	15.00	70	5.36
30	12.50	75	5.00
35	10.71	80	4.69
40	9.38	85	4.41
45	8.33	90	4.16
50	7.00	95	3.95
55	6.82	100	3.75
60	6.25	105	3.57

With chain transmission between engine and propellers, and including the losses in transmission, the overall efficiency between the engine and the useful work of propulsion will not usually exceed 50 to 60 per cent. With direct connection as in the typical monoplane the overall efficiency may range some 10 per cent. higher. Hence the thrust per engine horsepower may be expected to range from .5 to .7 these values.

Illustrative Problem:

i.h.p. = 80

th.h.p. = 45

Speed = 60 m.h.

Then $T = 6.25 \times 45 = 281.25$

In equation (1), section (2) let $m = .5$ and $u = .30v$

Then $v = 60 \times 1.47 = 88.2$ f.s., and $u = .30 \times 88.2 = 26.46$ f.s.

Then substituting in (1) we find

$$A = \frac{315 \times 32.16 \times 13.16}{101.43 \times 26.46} = 49.68$$

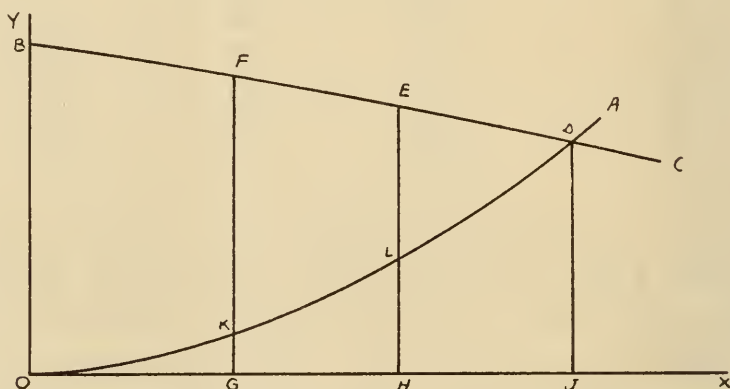
or $D \ 7.95 \text{ feet} = 8 \text{ feet approximately.}$

Note may here be made of the difference between the thrust when stationary and when moving in free flight, both with a given engine torque.

This is only a special case of the more general problem of the variation of thrust with speed, the engine torque or turning moment remaining constant. See also section (10).

In such case it is found in general, with increasing speed, that the slip and thrust will decrease, while the useful and total work will both increase. *Vice versa*, with decreasing speed the slip and thrust will increase and the useful and total work will both decrease. It results that with a given torque the thrust, when the speed is zero, has its largest value, while the revolutions and total work have their lowest values, and the useful work is, of course, zero.

FIG. I.



OX , axis of speed; OY , axis of resistance and of thrust; OA , curve of resistance on speed; BC , curve of thrust on speed. Intercepts KF , LE , etc., show amount of thrust available for acceleration.

These relations should be borne in mind in connection with pulling or thrust tests of propellers with the aëroplane or boat stationary. The thrust or pull developed in such a test is always much in excess of that developed in free flight, while the revolutions and power developed by the engine are less. It results that the engine connected to a propeller does not develop its full power when the boat or aëroplane is stationary. The turning moment may be developed by the engine, but the resistances are such that it is balanced by a combination of high slip and low revolutions, and hence with correspondingly reduced power. Where the craft is free and in motion the slip is reduced, and to balance the constant torque higher revolutions are required, resulting, with

the influence of other factors, in a reduced thrust, increased speed, and in increase in both the useful and the total work.

These relations may be further illustrated by the curves of Fig. 1.

(4) PROPELLER ACTION FROM CONSIDERATION OF FORCES ON AGENT.

We may next consider briefly the derivation of certain relations based on the second viewpoint of propeller action, the consideration of the forces acting on the blade rather than the accelerating effect on the medium.

In the diagram, Fig. 2, let the heavy line denote a small elementary plane which may thus represent an element of an ideal screw propeller.

OK is the direction of movement of the boat or aëroplane relative to the earth or the surrounding still water or air.

OE is the direction of motion of the element relative to the boat.

Suppose the element to rest and move on a smooth, unyielding surface. In other words, suppose that there is no yield to the medium—no movement of the element relative to the medium other than edgewise through it. Then it is clear that while the element moves transversely from O to E it must move forward with the boat a distance equal to EF .

This would mean operation without propeller "slip."

Actually the distance moved forward will be EG some distance less than EF .

The distance EF for one revolution of the propeller is known as the *pitch*.

Let us use the following notation:

p = pitch = EF for one revolution.

D = diameter.

N = revolutions per minute.

s = slip ratio $FG \div EF$.

$(1 - s)$ = ratio $EG \div EF$.

r = radius of element of area relative to shaft centre.

dA = element of area of surface.

A = total propeller surface.

T = thrust or pull in direction of motion of craft.

R = force opposed to motion of propeller element relative to craft.

P = normal force on element.

- Q = tangential force on element.
- v = speed of craft forward.
- w = speed of element relative to craft.
- U = useful work of propulsion = Tv .
- e = efficiency.

Let OE now represent specifically the transverse distance moved by the element in one revolution. Then :

$$\begin{aligned} 2\pi r &= OE \\ p &= EF \\ \tan \theta &= p \div 2\pi r \\ p &= 2\pi r \tan \theta \dots\dots\dots (5) \end{aligned}$$

Again, if we consider the diagram as representing the distances moved in unit of time, we shall have

$$\begin{aligned} EF &= pN. \\ OE &= 2\pi rN. \\ EG &= v = pN (1-s). \end{aligned}$$

whence in general

$$v = PN(1 - s) \dots\dots\dots (6)$$

$$s = \frac{pN - v}{pN} \dots\dots\dots (7)$$

Now, whatever the exact distribution of forces on the surface of the element, they may be represented by a normal force P and a tangential force Q , as indicated in the diagram. Then R , the total resistance to transverse movement, will be the sum of the components of P and Q on a transverse line, represented graphically by AB .

Likewise, T , the total resultant along the direction of motion OK , will be the sum of the two components along this direction, of which that for P is positive or forward and that for Q is negative or astern. The algebraic sum or net forward resultant is represented graphically by DC .

These resultants have values as follows :

$$\begin{aligned} T &= P \cos \theta - Q \sin \theta \} \dots\dots\dots (8) \\ R &= P \sin \theta + Q \cos \theta \} \end{aligned}$$

Then Tv = useful work and $2\pi rNR$ = total work.

Also efficiency :

$$e = \frac{Tv}{2\pi rNR} = \frac{(P \cos \theta - Q \sin \theta)v}{2\pi rN(P \sin \theta + Q \cos \theta)} \dots\dots\dots (9)$$

It will be apparent that, with other things the same, the efficiency will be greater as Q is less, and less as Q is greater. In the limiting case when $Q = 0$ we shall have

$$e = \frac{Pv \cos \theta}{2\pi r NP \sin \theta} = \frac{v}{2\pi r N \tan \theta} \dots\dots\dots (10)$$

If now $N = 1$ we shall have $v = EG = PN (1-s)$. But from (5) $2\pi r \tan \theta = \text{pitch}$, whence (10) becomes

$$e = \frac{pN (1-s)}{pN} = (1-s) \dots\dots\dots (11)$$

This, therefore, represents the limiting value of the efficiency for a thin plane acting as an element of a screw propeller.

With thickness on the back as in the section of an actual propeller blade, there is experimental evidence that at high values of the slip the actual efficiency may pass this limiting value where s is computed for the pitch on the rear or driving face. The explanation is found in the fact that with thickness the virtual or effective pitch is no longer that of the rear face, but a greater value. This effect depends on the disposition of the stream lines about a body of the form of a propeller blade section. It is very complex in detailed analysis, and can only be here referred to in an incidental way.

In order to make further progress in the development of these equations (8), (9), we must make some assumption regarding the forces P and Q . Only an outline of the procedure to be followed can be here given.

We may assume P and Q in accordance with the following principles and approximate relations:

(1) Hydrodynamic forces, such as those here considered, vary closely with the area and with the square of the relative velocity between blade and medium.

(2) Through the slip and the pitch ratio ($p \div D = \pi \tan \theta$) the relative speed of the element through the medium may be related to the speed PN .

(3) The forces P and Q are related to thrust T through the angle θ , and hence through the pitch ratio.

Hence we may write

$$T \propto dA (pN)^2$$

$$\text{Then } U = Tv = Tpn(1-s)$$

$$\text{Whence } U \propto dA (pN)^3$$

Now for a propeller as a whole made up of a series of such elements we shall have

$$A \propto D^2$$

Hence we may write finally

$$U \propto D^2(pN)^3$$

We must now inquire as to the content of the sign of variation or relation, (\propto). On what characteristics and factors of operation will the relation depend? Obviously on all distinguishing characteristics and factors which are not explicitly represented in the formula. These may readily be seen to comprise the following:

- (1) The slip ratio s .
- (2) The pitch ratio $P \div D$.
- (3) The area ratio = total area of blades $\div (\pi D^2/4)$.
- (4) The form of the blade.
- (5) The thickness of blade and its disposition.
- (6) The character of the surface as to smoothness and continuity of form.

We may therefore, if we desire, write

$$U = BD^2(pN)^3 \dots\dots\dots (12)$$

where B is a general factor representing the combined influence of these six factors or influences. Or, again, we may write the equation

$$U = abcdefD^2(pN)^3 \dots\dots\dots (13)$$

where the various factors a, b, c , etc., each represent the individual influence of the various characteristics and conditions (1) . . . (6).

In so far as any of these may be made standard,—that is, in so far as variation in these characteristics may be eliminated,—in corresponding measure may we eliminate or discard the corresponding factors. Thus if we may assume (6) to be practically standard or uniform, and if we can assume (5) standard,—that is, always associated in a definite and regular way with certain of the other characteristics, such as diameter and blade area,—then we could discard e and f and reduce the number of factors to four. If, in addition, we could assume a standard form,—that is, a form always definitely and regularly associated

with diameter and area,—then d could be discarded. If, further, we could assume a standard area ratio,—that is, an area always bearing a fixed relation to D ,—then we could discard c and thus retain only a and b , the factors relating to pitch ratio and to slip ratio.

On the other hand, to the extent to which these various characteristics can not be made uniform or standard, to such extent will the performance of the propeller depend on such variable features and to a corresponding extent should a complete propeller formula contain factors intended to represent these various conditions.

Referring in general to the two methods of viewing propeller action, and in particular to the equations which directly result from such methods—(1), (12), (13)—it develops that in neither the one case nor the other do the resulting equations by themselves serve to establish any complete or satisfactory relation between the characteristics of the propeller and the general schedule of requirements to be met.

In particular, from the first method of consideration, the simple theory which can be thereon developed does not serve to determine quantitatively how much water or air a given propeller will lay hold of or how much it will accelerate its motion. It does not serve, therefore, as an adequate basis for the actual design of a propeller suited to a specified program of requirements. Similarly, the second mode of consideration does not serve to determine quantitatively the forces which act on the blade of a given propeller, or their distribution over its surface. Specifically in equations (12) and (13) the theory as developed furnishes no basis for the numerical computation of the general factor B or of any of the various factors a , b , c , etc., which go to make up its complex value.

It results that only through experimental research or the investigation of actual cases can we determine the numerical values of the factors which thus stand between the simple theory and the requirements of actual design.

To this end equations (12) and (13) are much more directly available than those furnished by the first method of consideration. In any case and whatever the viewpoint, the equations must be thrown substantially into the form of (12) or (13) before they can be readily applied to the purposes of design.

(5) APPLICATION TO PROBLEMS OF DESIGN.

The practical question now arises, supposing that we know or have given a value of B in (12) or of a , b , c , etc., individually in (13), to what extent and under what limitations can such values be used for purposes of design? This question is of fundamental importance, and the answer should be clearly and accurately understood and its full significance realized. The answer is found in the following:

(1) For purposes of design it is assumed that the mutual forces acting between a solid body and a fluid medium in relative motion depend upon and are determined by the relative velocity and the various other characteristics and conditions as outlined in (1) to (6) above.

(2) That for a given solid body at varying speeds these forces vary directly as the square of the velocity.

(3) That for geometrically similar bodies but varying in absolute size, moving with geometrically similar relations to the medium and hence with geometrically similar systems of stream-line distribution, the total forces at speeds proportional to the square roots of the linear dimension will be proportional to the cubes of the linear dimensions.

Assumption (3) expresses in effect the application of the law of kinematic similitude or of "comparison" so-called, as applied to hydrodynamic problems of this character.

Without taking space for minor details, it is readily shown that these assumptions are equivalent to the statement that in equations such as (12) and (13) the factor B or the various individual factors a , b , c , etc., are independent of absolute size and of absolute speed and can therefore be applied independent of size or speed and dependent only on the particular proportion or characteristic which they are intended each to represent.

It thus results that if for a given propeller we can establish a series of values for a given set of conditions (1) to (6), we may then use these same factors for any propeller, no matter what the actual size or the actual speed, so long as the same set of characteristics and conditions (1) to (6) is fulfilled.

If, then, by means of experimental propellers a sufficient number of experiments could be carried out to furnish a wide range of these factors corresponding to all combinations of the

various characteristics and conditions, the problem of propeller design would be put on a reasonably definite and secure basis. Actually no such collection of data is now available, and present dependence must be placed on somewhat widely scattered results.

It must not be forgotten, moreover, that the independence of these various factors on absolute size or speed is, after all, only an assumption made for the purpose of convenience. With reference to a more refined analysis, it cannot be doubted that both size and speed will have some influence on their values, and hence it should be remembered that in the application of experimental results, or in transferring the results for a given case to the circumstances of a proposed case, the more remote the two cases in point of size and speed, the less certain will be the results; and the nearer they are in these respects, the more dependable will be the results.

The application of the general equation (12) for purposes of design may be shown by a few simple illustrations.

For a given propeller we have the following dimensions and results:

$$\begin{aligned} D &= 7 \text{ feet.} \\ p &= 7.7 \text{ feet.} \\ N &= 700. \\ v &= 48 \text{ miles per hour.} \\ \text{i.h.p.} &= 45. \end{aligned}$$

What should be the diameter of a geometrically similar propeller to absorb with the same slip ratio an i.h.p. of 60 with a speed of 51 miles per hour?

Equation (12) is equivalent to the following statement:

Under similar conditions the power absorbed by a propeller is proportional to the square of the diameter and to the cube of the product pN . Hence,

$$\frac{60}{45} = \frac{D_2^2}{49} \left(\frac{p_2 N_2}{p_1 N_1} \right)^3$$

But with equal values of the slip ratio s , the product pN will vary as the speed v . Hence we have

$$\frac{60}{45} = \frac{D_2^2}{49} \left(\frac{51}{48} \right)^3$$

Whence

$$\begin{aligned} D_2 &= 7.38 \text{ feet} = 7 \text{ feet } 4.5 \text{ inches} \\ p_2 &= 1.1 \times 7.38 = 8.12 \text{ feet} = 8 \text{ feet } 1.4 \text{ inches} \\ p_2 N_2 &= \left(\frac{51}{48} \right) 7.7 \times 700 = 5726 \\ N_2 &= 5726 \div 8.12 = 705 \end{aligned}$$

Suppose, again, a propeller similar in geometrical form to No. 1, but 20 per cent. smaller in size. At a speed of 60 miles per hour how much power will it absorb under the same circumstances and with the same slip as No. 1?

Since the slip ratio is the same we must have the product pN in the ratio of the speed.

Hence

$$p_2 N_2 = p_1 N_1 \times \frac{60}{48} = 7.7 \times 700 \times \frac{60}{48} = 6737$$

But

$$p_2 = 7.7 \times .80 = 6.16 \text{ feet.}$$

Therefore

$$N = 6737 \div 6.16 = 1094.$$

$$\begin{aligned} \text{Then i. h. p.} &= 45 \times (.8)^2 \times (1.25)^3 = 45 \times .64 \times 1.95 \\ &= 56.2 \end{aligned}$$

(6) SLIP OF PROPELLER AND STERNWARD ACCELERATION OF MEDIUM.

The term slip is sometimes used loosely with reference either to the medium or the propeller. The slip of the propeller is, however, not the same thing as the sternward acceleration of the medium. Each of these has been suitably defined in the preceding paragraphs. They are entirely different physical quantities. Comparing the slip of the propeller, FG (Fig. 2) with the sternward acceleration u in section (2), and denoting the former per minute by S , it may be shown that in the case of an ideal blade without friction we shall have

$$u = 2S$$

In the actual case with friction, no general relation can be established, but as a broad rule u will be less than the above value for the ideal case.

(7) REACTIONS BETWEEN CRAFT AND PROPELLING AGENT.

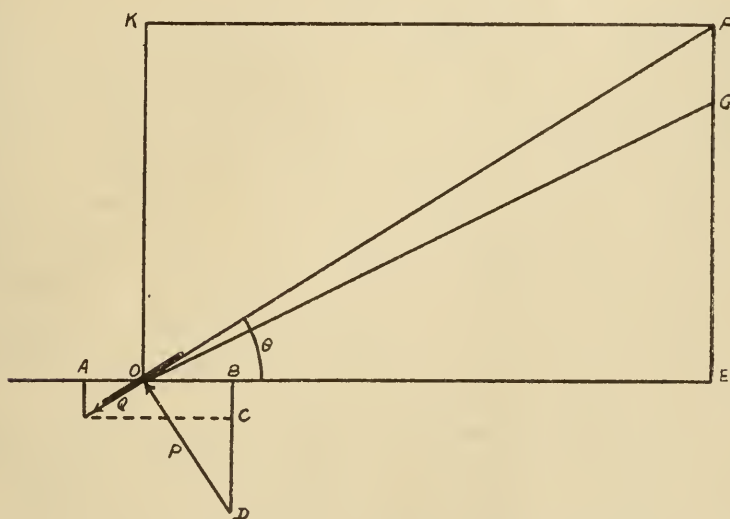
We must next consider briefly the mutual relations between the boat or aeroplane and the propelling agent. These relations may be noted under two heads, as follows:

(1) *Reaction of Propeller on Craft*.—This is in the nature of an augmentation of resistance as compared with the force which would be required to maintain the craft alone, drawn or forced through quiet air at the same speed. In the case of pro-

pellers located in the rear and operating by thrust, this augmentation comes by way of a driving or pumping of the air away from the after parts of the structure, thus diminishing the air pressure on these parts compared with the pressure which would prevail if the craft alone and without propeller were drawn or forced through the air at the same speed. This action is then, in effect, a diminution of the following air pressure on the structure, and a resulting increase in the difference between the resultant pressures acting from forward aft and from aft forward, and a consequent increase in the resistance opposed to propulsion.

In the case of propellers located at the bow (tractors) the augmentation comes by way of a current or blast of air driven

FIG. 2.



Force reactions between element of blade and medium.

aft by the propeller against the forward surfaces of the structure, thus increasing the pressures directed from forward aft, and hence increasing the difference between the resultants in the two directions, and hence the resistance to propulsion.

(2) *The Reaction of the Structure on the Propeller.*—This comes by way of a disturbance of the air in which the propeller operates, thus modifying in effect the slip ratio, and thus one of the fundamental conditions of operation.

With the propeller forward, as in the tractor, this reaction is small, and for practical purposes may probably be considered as negligible. With the propeller astern the action is more pro-

nounced. The motion of the structure through the air tends to develop a following wake of air, closing in about the propeller to a greater or less degree and constituting a sort of following current in which the propeller operates. With water and the usual ship-formed body this action is very pronounced, and must be considered in any careful analysis of the problem of propulsion. In the case of the ordinary biplane structure and a gaseous medium such as air it may be expected that the following current will be less pronounced than with the usual boat-formed body and a liquid medium. Nevertheless, the same principles obtain in the two cases, and the likelihood of some reaction similar to that in the case of water should not be overlooked.

The air thus acted on will be thrown into turbulence, and the practical result will be that the propeller is forced to operate in a turbulent medium with a small component velocity forward. The general effect of turbulence is to decrease the thrust developed, other things being equal, while the effect of the following resultant motion will be to increase the actual slip and thus to give a greater thrust than that due to the conditions of motion relative to the outlying body of quiet air. These two influences are opposite in direction. To what extent they will annul each other is not known with satisfactory exactness. In the case of water propulsion there is a marked resultant increase in the thrust. In the case of air it seems probable that the resultant action will be similar, but less in amount.

These two reactions between the propeller and the craft thus presumably trend in opposite directions. The reaction of the propeller on the structure tends to increase the resistance and thus the actual propeller thrust which must be developed. On the other hand, the reaction of the following current tends to place the propeller in such conditions of operation that the needed thrust is realized with lower revolutions and hence with less power than would be the case in undisturbed air.

In the case of water propulsion these two effects very closely counterbalance so far as the final work of propulsion is concerned. In the case of air propulsion, further experimental data are required before any definite statement can be made regarding this point.

In considering this matter of the reaction between the structure and the propeller, a final point should be noted in connection

with the two values of the slip and the corresponding two values of the efficiency which may present themselves for consideration.

Thus the speed through the air, considered as a surrounding quiet medium, is a matter of direct observation. So also are the revolutions. The pitch of the propeller is known.

The slip $s_1 = (pN - v)/pN$ is a simple matter of observation. It is not, however, the actual slip of the propeller relative to the air in which it works. Suppose that the air about the propeller has an effective following velocity measured by wv where w is some small factor. Then the velocity of the propeller through or relative to this air is $v - wv = (1 - w)v$. The true slip, that relative to the air in which the propeller is actually working, will be therefore measured by

$$s_2 = \frac{pN - (1 - w)v}{pN}$$

From these we readily derive the following:

$$1 - s_1 = \frac{v}{pN}$$

$$1 - s_2 = \frac{(1 - w)v}{pN}$$

$$\frac{1 - s_2}{1 - s_1} = 1 - w$$

The slip s_1 is usually called the apparent slip and s_2 the true slip. Corresponding to these we have two values of the propeller efficiency, one as determined by the apparent slip in conjunction with the other characteristics, and called the apparent efficiency, and one as determined by the true slip with the other characteristics, and called the true efficiency.

(8) SIDE TIPPING MOMENT DUE TO TORQUE.

Since action and reaction are equal, it is clear that the turning moment developed by the engine will tend equally to rotate the shaft relative to the aeroplane and the aeroplane relative to the shaft. The shaft rotates rather than the structure of the aeroplane simply because there is less resistance to such rotation. The moment exists, however, and would produce a slow rotation of the structure in one direction and a rapid rotation of the shaft in the other but for the corrective effect of ailerons or of

a pendulum, disposition of the weights of the structure, or both in combination.

The magnitude of this tipping moment is readily determined from the horsepower and revolutions.

Thus let W = power developed by engine in i. h. p.

Q = torque

N = r.p.m.

Then $W = 2\pi NQ$

or $Q = \frac{33000 W}{2\pi N}$

Thus for illustration, if $W = 90$ and $N = 900$, we have

$$Q = \frac{33000 \times 90}{2\pi \times 900} = 525 \text{ pound feet.}$$

This would be equivalent to two equal forces of about 26 pounds each, acting one up and the other down, with an arm of 20 feet between them.

If the weights of the structure are so disposed as to give a pendulum effect,—that is, a righting moment due to gravity,—then without aileron effect the structure will incline until the righting moment thus developed equals the tipping moment developed by the engine torque. With aileron control the result will be a combination of the two factors, the details of which will depend on the circumstances of the case.

In the case of twin propellers rotating in opposite directions, as in the typical Wright biplane construction, these moments are equal and in opposite directions and thus balance, leaving the propulsive effort without residual turning moment on the craft.

(9) LONGITUDINAL TIPPING MOMENT DUE TO THRUST.

The thrust is applied approximately along the line of the shaft. The centre of resistance of the structure with any particular configuration of planes, ailerons, and rudders may lie above, below, or on this line. If it should lie above the line the combination of the thrust and the resistance will form a couple tending to elevate the head of the structure. If it lies below the line the result will be a couple tending to depress the head, and if on the line there will be no such couple and the angular aspect of the structure will not be affected. It may thus result that a given machine will require a constant corrective use

of the vertical rudder to control this tendency for either the head or the tail to lift. Such a result implies an improper disposition of weights or plane surfaces relative to the location and direction of the shaft. Such a continued or set condition of a vertical rudder, while it may serve to correct the tendency to curving flight, will nevertheless be at the expense of an increased resistance and a corresponding loss in speed for the same engine power.

(10) ACCELERATION OF SPEED FROM REST TO FINAL STEADY CONDITION.

Another topic closely related to the variation of thrust with speed, the engine torque being constant, is the gaining of speed from a condition of rest.

It will be clear for any given value of the engine torque with a given propeller and craft that there will be some speed of advance for which the thrust or pull developed by the propeller will be exactly balanced by the resistance developed by the craft, and hence a condition of steady flight will result. If, however, the speed has some value v less than this final steady condition speed v_1 , then the resistance will be correspondingly less while the thrust will in general be actually more. It will result that there will be a part of the thrust not balanced by the resistance and hence available as an accelerating force. In answer to such force the speed will gradually increase, closing down the gap between v and v_1 and thus approaching the final value v_1 .

With the increase in speed, however, there will come a corresponding increase in resistance, a resultant decrease in the margin available for acceleration, and a resultant decrease in the rate of closing the gap in speed. Thus at the start from rest the entire thrust is available for acceleration and the acceleration in speed is correspondingly large. This steadily decreases as the speed increases, and there is thus a gradual approach with a slower and slower acceleration to v_1 , the final speed for steady flight. It is of interest to note that under ideal conditions,—that is, with absolutely quiet air and uniform engine torque,—the equations for these relations take such form as to show that the time and distance required for the ultimate realization of the final speed v_1 would both be infinite. The physical reason for this is found in the gradually-decreasing value of the acceleration

as the gap to be closed becomes less. The speed v_1 from rest thus represents the summation of a series of terms, infinite in number and indefinitely decreasing in magnitude with increase of time. In the same way the time required to fully realize any increase in speed corresponding to a change in engine torque would theoretically be indefinitely great.

In a similar manner with a given condition of steady flight, if the engine torque is reduced there will be an excess of resistance over thrust which will operate as a retarding force. This will reduce the speed gradually from v toward the smaller steady condition value v_1 . In a similar manner, likewise, the retarding force will decrease as the difference between v and v_1 is less, and the gap will therefore be closed by an indefinitely diminishing series of elements. In this case, the same as for gaining speed, ideal conditions give equations indicating an indefinite time and indefinite distance for realizing the ultimate speed corresponding to the reduced torque.

Actually the important question is not the time or distance required to realize the ultimate speed corresponding to a given engine torque, but rather the time or distance required to realize a substantial closure of the gap between the original speed v and the final speed v_1 . Thus if the total ideal change is .90 or .99 realized, the result is a substantial fulfilment of the conditions, and the time and distance for such practical fulfilment are always finite quantities, large or small, according to the factors and circumstances of the case.

Actually, moreover, the conditions regarding resistance and engine torque are never perfectly uniform. The resistance is constantly changing, due to varying external conditions and the torque due to varying conditions affecting the motor. The result of these various interacting factors is a continually changing state regarding speed and acceleration in which there is a constant effort on the part of the forces involved to maintain an adjustment with the changing conditions, but in which there is a time lag, so that the adjustment is always lagging behind the changing conditions.

These circumstances furnish an illustration of a problem of pursuit in which the changing speed may be said to be continually in pursuit of the changing conditions, but always lagging behind in the race.

These relations are further illustrated by the diagrams of Fig. 3.

(II) CENTRIFUGAL FORCE ON BLADES.

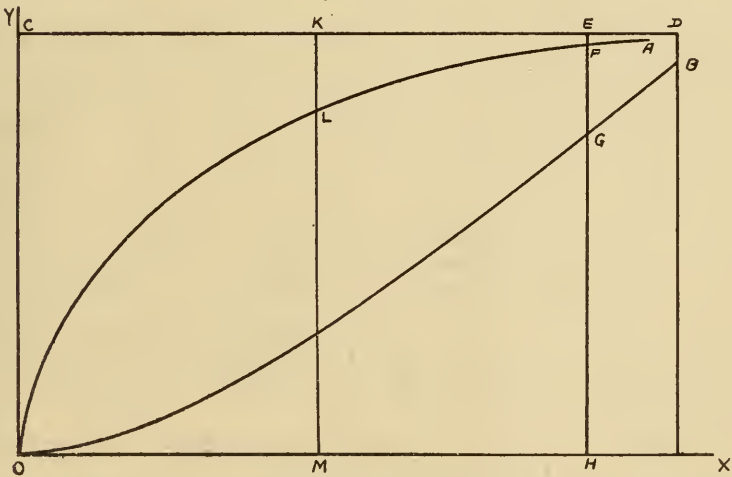
At high rotative speeds the centrifugal force developed may become a matter of importance with reference to the stresses developed at the root of the blade.

- Let W = weight of blade.
- r = radius of centre of gravity.
- ω = angular velocity.
- n = revolutions per second.
- F = centrifugal force.

Then from mechanics we have

$$F = \frac{Wr\omega^2}{g} = \frac{4\pi^2n^2Wr}{g}$$

FIG. 3.



OX , axis of time; OY , axis of speed and of distance; OA , curve of speed on time; OB , curve of distance on time; CD , line of steady speed toward which actual speed approaches as a limit. Intercepts KL , EF , etc., = speed increments yet to be gained at any time OM , OH , etc.

Thus for illustration let r.p.m. = 600, $W = 20$, $r = 1.8$.

Then $n = 10$ and $F = 4440$ pounds.

If r.p.m. = 1200, $n = 20$ and $F = 17,760$.

Forces of this magnitude will naturally require special consideration with reference to the strength at the root section of the blade for the usual two-bladed form, or with reference to the blade fastenings for the three-bladed form.

(12) EFFECT OF ALTITUDE ON THE OPERATION OF A PROPELLER.

All formulæ for the resistance to the motion of a solid through a liquid or gas contain the density of the medium as a direct factor. It results that the resistance of the *aéroplane* to propulsion, the lifting force developed by the action of the air on the planes, the propulsive thrust developed by the propeller, and the resistance to transverse movement in opposition to the torque of the engine will all vary directly with the density of the medium, other conditions remaining the same.

It results further, since the weight of the *aéroplane* remains unchanged, that the constant lifting force must be developed as a result of either (1) increased speed or (2) variation of angle of incidence of planes, or some combination of both. Remembering, furthermore, that resistances, thrusts, and lifts vary approximately as the square of the speed, it follows that if the engine is giving a constant torque we shall have the following combination of results. As the altitude increases and the density of the air decreases the propeller will speed up until at some combination of increased rotative speed and varying slip the steady turning moment of the engine will remain balanced by the transverse resistance opposed to the passage of the blades through the air. Since, however, the lifting force must remain the same (for horizontal flight) and all forces and resistances involving the air are varying in the same manner with the density, it will further result that at the same angle of incidence the thrust will be the same and the slip ratio will remain nearly constant. Steady conditions will then be realized and maintained with a rotative speed varying inversely nearly as the square root of the density, with a speed of flight varying in the same manner, with the lift and thrust constant, with the torque constant (as assumed), and with a power output varying directly with the speed or nearly in the inverse ratio of the square root of the density.

If the angle of incidence is varied with altitude the result becomes more complex and cannot be determined in general terms. Thus if the angle is increased with altitude the thrust and resistance must be greater for the same lifting force. The slip will therefore increase and the increase in revolutions, speed, and power output will be less than for constant incidence.

It must be further remembered that the engine at high alti-

tudes will not give the same torque without corresponding adjustments governing the power developed. The air and fuel indraft per stroke will decrease with the density, and without compensating adjustment the torque cannot be maintained constant. It may be further noted that with increasing rotative speed a constant torque will require greater energy developed per stroke or per cycle, increasing directly with the speed. Hence constant energy per stroke or per cycle will not maintain a constant torque with increasing altitude, and hence will not maintain a constant lift without adjustment of the angle of incidence.

Thus for illustration at 10,000 feet elevation as compared with sea level, the density ratio without regard to change of temperature is about .68. The square root of this is .825, and the reciprocal of .825 is 1.21. Then for horizontal flight with constant engine torque and angle of incidence the thrust and lift will remain the same, while the rotative speed, speed of flight, and power output will all increase by approximately 21 per cent.

(13) GEOMETRY OF THE SCREW PROPELLER.

Imagine a generating line AB with one end rigidly fixed to a sleeve or hollow tube which slides on a straight line guide or axis. Such a system may be moved either in rotation or axially or both (see Fig. 4).

The *diameter* of the surface thus generated is naturally the diameter of the cylinder which will just inclose it.

The *pitch* is the axial distance corresponding to a complete revolution of the generating line.

Four variations in the generating line may be noted, as follows:

- (1) Straight and at right angles to axis.
- (2) Straight and inclined to axis.
- (3) Bent or curved in an axial plane.
- (4) Bent or curved in a transverse plane.

In any of these cases if the axial and angular movements are in constant proportion, the surface traced by the generating line is called a true helical surface or a surface of *uniform* pitch. If the axial movement varies in proportion with the angular movement, the surface is said to have an axially variable pitch.

Take the case of a straight line generatrix, and generating a surface of uniform pitch. Suppose the surface inclosed by a

cylinder on the surface of which the end of the generatrix will trace out a helical spiral path, $KLMBN$ of pitch = PQ .

Let the surface of the cylinder be developed as in Fig. 5. AB represents the developed circumference, πD ; BC represents the pitch p , and, as well known, the spiral path develops into the diagonal AC .

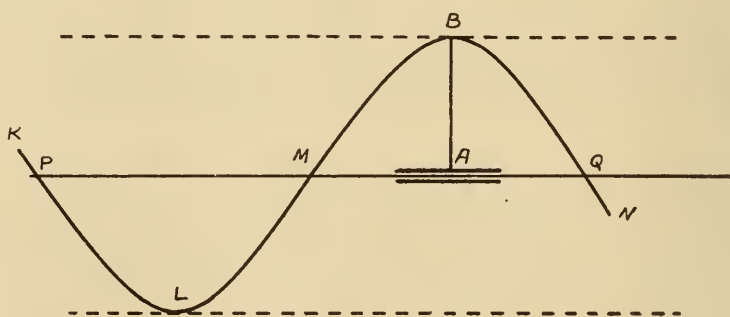
Let θ = angle of inclination of AC to AB .

Then obviously

$$p = \pi D \tan \theta = 2\pi r \tan \theta.$$

Now imagine a helical surface of the most complex character, such, for example, as that given by the rounded back of an ordinary propeller blade, or any other surface smooth and con-

FIG. 4.



Geometry of screw propeller. Generation of helical surface.

tinuous, but not possible of generation by any line moving as above specified. It will be clear that for any small element of such a surface we shall be able to find a true helical surface with the same outside diameter, with a straight generatrix either at right angles or inclined to the axis, and just tangent to the element in question. The pitch of this tangent surface is taken as the measure of the pitch of the element. In this sense any element of surface may be said to have a pitch relative to a specified axis and diameter.

The *face* or *driving face* of a propeller blade is the surface which receives the excess pressure of the air resulting in the propulsive force. It is the after or rear face relative to the craft which it is driving.

The *back* of a blade is the forward surface, opposite the face.

The *leading edge* is the forward or entering edge relative to the movement of the blade through the air.

The *following edge* is the rear or leaving edge relative to the movement of the blade through the air.

The face of the blade is part of a helical surface formed according to some definite law as regards pitch, and usually with straight generatrix at right angles to the axis and with uniform or axially variable pitch.

In the latter case the variation is such as to increase the pitch from the leading to the following edge. This is usually known as an axially expanding pitch.

More broadly it may be seen that any combination of pitch elements may be combined giving variation from centre to tip as well as from leading to following edge and according to any law as may be desired.

The form of the back is determined simply by the need for strength and for thickness to give the requisite material. As will be realized from the broader view of a helical surface, the back may also be considered as such a surface with an extremely variable distribution of pitch. As usually employed, the term pitch refers solely to the driving face. Actually, however, the back may be viewed as composed of a series of elements of surface, each with its pitch as determined by its location and shape. It results that in reality the propeller blade is bounded by two surfaces: a driving face with a uniform or fairly regular distribution of pitch, and a back with an extremely variable distribution of pitch.

The word pitch must therefore be considered as having two meanings or two applications:

(1) The *geometrical pitch*, which refers solely to the driving face and is simply a matter of the form of this surface.

(2) The *dynamic pitch*, which refers to the real dynamic effect of the blade as a whole, with its two bounding faces, each of which has its due influence on the forces acting between the propeller and the medium in which it works.

The former is the usual sense in which the word is employed. It can be determined by simple geometrical measurements. The latter cannot be so determined and can only be inferred as a result of experimental research. In general such investigation shows that the dynamic pitch is greater than the geometrical.

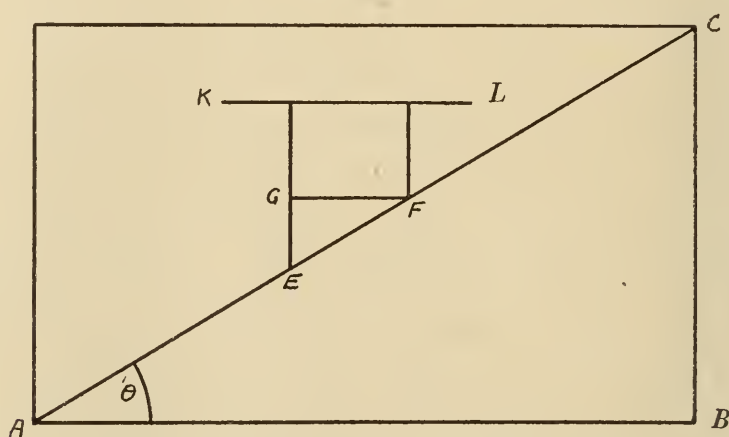
Screw propellers for air craft are usually of wood, with the blades set opposite, permitting of construction by means of con-

tinuous layers, crossing the centres, and thus securing greater strength at the hub than in the case of interrupted blades, as with three- or four-bladed forms.

(14) MEASUREMENT OF PITCH.

A practical problem which may arise relates to the measurement of the geometrical pitch. If the blade is of uniform pitch it will obviously make no difference where the measurements are made: the results should be the same. If it is of variable pitch it must be measured at a sufficient number of points to permit the determination of the general law of variation.

FIG. 5.



Geometry of screw propeller. Developed true helix.

Referring to the equation relating pitch to diameter and angle of inclination we have

$$p = \pi D \tan \theta.$$

At any selected point, then, we have simply to measure the diameter and the tangent of the angle θ .

We may first note that where $\theta = 45^\circ$ $\tan \theta = 1$ and $P = \pi D$.

A quick determination may therefore be made by finding the diameter where $\theta = 45^\circ$ and then taking the pitch $= \pi D$, the circumference on this diameter.

For any selected point we may follow a more general procedure, as follows:

Divide the problem into the four steps:

- (1) Select the point and measure the corresponding radius.
- (2) Determine a plane of reference perpendicular to the axis of the propeller.

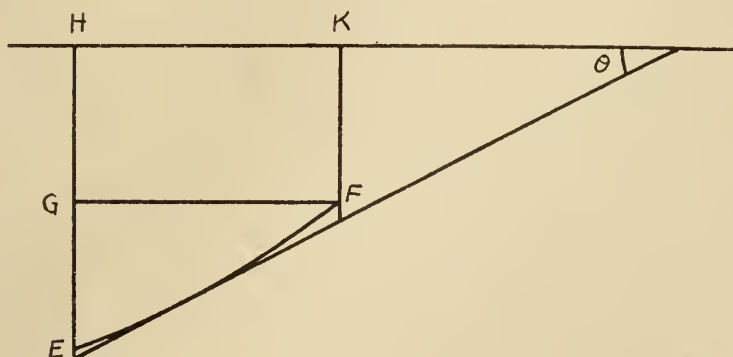
(3) Lay out on the face a line representing the locus of all points distant the given radius from the axis. This is equivalent to laying out on the face a line representing its intersection with the surface of a cylinder on the same axis, and with radius equal to that for the given point on the blade.

(4) Select two points on this line and measure their distance apart on the line and their distances from the reference plane.

Then, referring to Fig. 5, it is plain that the distance between the two points on the line is EF and the difference between the two distances from the plane is GE . Then obviously $\sin \theta = GE/EF$, and

$$\tan \theta = GE / \sqrt{EF^2 - GE^2}$$

FIG. 6.



Developed guide iron for axially variable pitch.

The details of these individual steps will be determined by the resources available, but with a little ingenuity a sufficiently accurate determination can be made with relatively crude appliances.

In any actual case it will be well to repeat the measurement at two or three different values of the radius as a matter of check and to ascertain the possibility of variable pitch at different radial distances from the axis.

This method will give in effect the mean pitch between the two points E and F . If the pitch is variable axially or at different points along EF , and a more accurate determination is desired, then the procedure noted above may be modified as follows:

(1) As before.

(2) As before.

(3) Bend a sheet of tin or thin sheet iron to the curvature of the surface of a cylinder of the given radius.

(4) By cutting and trying fit this sheet so that one edge lies in the plane determined by (1) and the other lies on the surface of the blade, while the sheet itself is in position on the surface of the imaginary cylinder.

This sheet (*EHKF*, Fig. 6) may then be developed out flat again, thus giving the triangle *EFG*. If the pitch is expanding axially the line *EF* will be curved as shown. Then the angle θ at any particular point will be the slope of the tangent to *EF* at that point. In this way the value of the pitch may be found at either leading or following edge or at other intermediate points as desired.

Action of Colloids on Radioactive Products. T. GODLEWSKI. (*Phil. Mag.*, xxvii, 618.)—It has been shown that on passing an electric current through a solution of radium emanation, together with the successive disintegration products, the radioactive substances were deposited almost exclusively at the cathode when the medium was acid or in presence of polyvalent cations and at the anode when the medium was alkaline or in presence of polyvalent anions. This suggests that the radioactive products are present as colloidal hydrosols and that the process is one of electrophoresis rather than electrolysis. Further experiments in which various colloids were added to the solution confirmed this view, and it was found possible to concentrate powerful radioactivity on a few milligrammes of a coagulated hydrosol (*e.g.*, colloidal gold or platinum coagulated by aluminum sulphate). Positive colloids can be precipitated merely by filtering through paper or glass-wool, and in this way radium B and some radium C can be separated from water saturated with radium emanation, the greater part of the β -activity from dilute solutions of uranium nitrate (up to 10 grammes per litre), and some of the disintegration products of thorium and actinium. If a small quantity of aluminum sulphate be added to water containing radium emanation, the negative hydrosols become inversely charged and all the products, radium A, radium B, and radium C, are then retained by a paper filter.

THE COMPUTATION OF COMPOSITE ALTERNATING-CURRENT LINES.*

BY

A. E. KENNELLY, Sc.D.,

Professor of Electrical Engineering, Harvard University.
Member of the Institute.

It is proposed to show how conveniently and swiftly the electrical characteristics of a composite alternating-current line can be computed by means of tables and charts¹ of hyperbolic functions. A composite line is defined as one consisting of a plurality of successive sections, each having its own uniform electric constants. It will be evident, from an example of the process, that the tables and charts referred to can be used without any necessary familiarity with the mathematical theory of hyperbolic functions. A moderate acquaintance with the working formulas of ordinary circular trigonometry suffices.

Before analyzing the case to be considered, a few preliminary relations may be outlined.

Every uniform conducting-line circuit, carrying steadily either continuous or alternating currents, overhead or underground, may be regarded as possessing, or subtending, a certain "hyperbolic angle," which is directly proportional to the length of the line, and also depends upon the electrical constants of the line, as well as on the frequency, but is quite independent of the strength or phase of the current carried by the line. The angle subtended by the line is the same whether the line is operated alone, forms part of a transmission system, or is an element in a network of conductors. The angle subtended by a line is, therefore, a fixed property of the line, when the frequency impressed on the line is fixed.

When the impressed frequency is zero,—*i.e.*, when the line is subjected to a continuous electromotive force,—the

* Communicated by the author.

¹ "Tables of Complex Hyperbolic Functions," and "Chart Atlas of Complex Hyperbolic Functions," by A. E. Kennelly, Harvard University Press, 1914.

angle θ subtended by the line is a simple number of what may be called "hyperbolic radians" (abbreviated "hyps."). A continuous-current line subtending 0.5 hyp. or less, would be a short line; but subtending 2.5 hyps. or more would be a long line. When, however, the line is subjected to an alternating electromotive force,—*i.e.*, when the impressed frequency is not zero, the angle of the line is a complex number of the type $\theta = \theta_1 + j\theta_2$ hyps. where $j = \sqrt{-1}$; so that θ comprises a real component θ_1 and an "imaginary" component θ_2 . The real component θ_1 of the complex hyperbolic angle θ is a hyperbolic angle, expressible in hyps., or is measured along the arc of a hyperbola. The imaginary component $j\theta_2$ is a circular angle, expressible in ordinary circular radians, or is measured along the arc of a circle.

The complex angle θ , subtended by a uniform line-section, is the geometrical mean of its total conductor impedance Z in ohms, and its total dielectric admittance Y in mhos, or $\theta = \sqrt{ZY}$ hyps. Thus, if a loop line has a total conductor impedance of, say, $Z = 200/50^\circ$ ohms, and a total dielectric admittance across the loop of, say, $Y = 0.8 \times 10^{-3}/70^\circ$ mho; then

$$\theta = \sqrt{0.16/120^\circ} = 0.4/60^\circ = 0.2 + j0.3466 \text{ hyp.}$$

If a line AB which subtends an angle θ is connected to ground, or zero potential, at one end, say, B , and to an impressed electromotive force at the other end A ; then the angle of the grounded end B is zero, the angle of the generator end A is θ ; while all intermediate points along the line may be regarded as possessing corresponding intermediate position-angles. Thus, the midpoint along the line has a position-angle $\theta/2$ hyps. If, however, the receiving end B , instead of being connected to zero potential by grounding or shorting, is connected to a terminal load of Z_r ohms impedance, then the angle at B is no longer zero; but θ' , as defined by the relation

$$\tanh \theta' = Z_r/Z_0 \quad \text{numeric } \angle (1)$$

where Z_0 is the surge-impedance of the line expressed by the formula

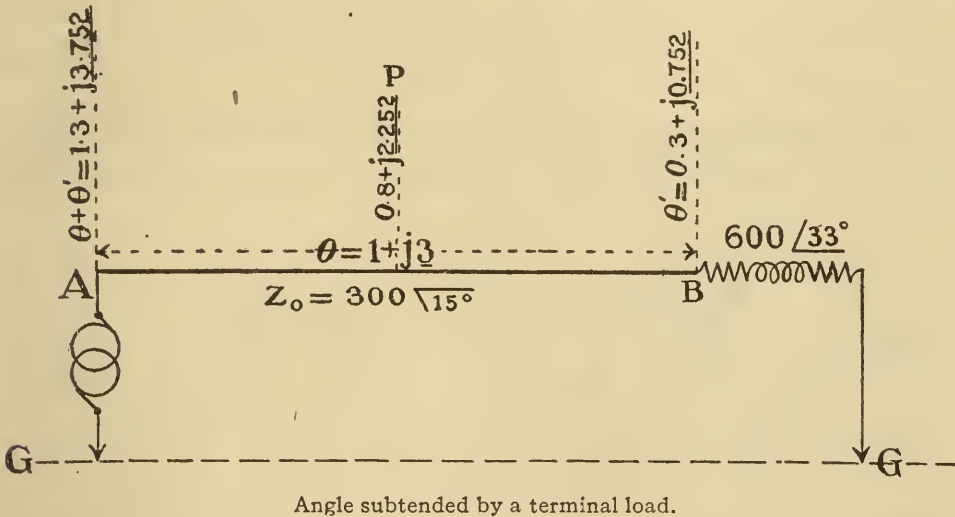
$$Z_0 = \sqrt{Z/Y} \quad \text{ohms } \angle (2)$$

The position-angle of the end A is then increased from θ to $\theta + \theta'$, and all the position-angles of intermediate points along the line become increased by θ' .

Every line, therefore, in addition to subtending an angle θ , depending on the frequency, possesses a terminal angle θ' at its motor end, which terminal angle depends both on the load and on the surge-impedance of the line. The position-angle δ_P at any point P on the line is the sum of θ' and that fraction of θ which its distance from B bears to the distance AB , or total line length.

The current at any point P on the line is then in simple proportion to the cosine of the position-angle, the potential to the sine of the position-angle, and the impedance to the tangent.

FIG. 1.



That is, in all cases, the magnitude and phases of currents and voltages are given by:—

$$\frac{I_P}{I_C} = \frac{\cosh \delta_P}{\cosh \delta_C} \quad \text{numeric } \angle (3)$$

$$\frac{E_P}{E_C} = \frac{\sinh \delta_P}{j \sinh \delta_C} \quad \text{numeric } \angle (4)$$

$$\frac{Z_P}{Z_C} = \frac{\tanh \delta_P}{\tanh \delta_C} \quad \text{numeric } \angle (5)$$

where C is some point on the line, ordinarily a terminal point A or B , at which the current I_C , the voltage E_C , and the position-angle δ_C are known.

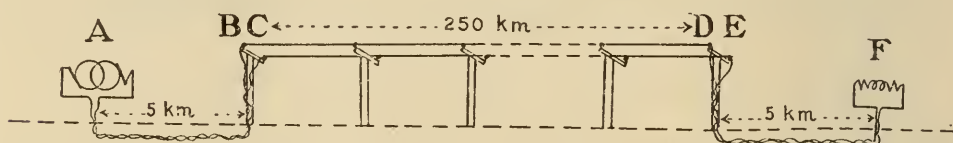
The foregoing relations are illustrated in Fig. 1, which represents a uniform conducting line AB , commonly one side of a metallic circuit pair, considered as operated, in single-wire fashion, to ground or neutral potential GG . At the generator end A

is an impressed alternating electromotive force of single frequency. At the motor end B is a terminal load of $600/\underline{33^\circ}$ ohms. At the frequency impressed, the line AB subtends, say, an angle $\theta = 1 + j\,3 \cdot \frac{\pi}{2}$ hyps, or $\theta = 1 + j\,3$, where the circular imaginary component is expressed, for convenience of computation, in quadrants instead of radians, and underscored to indicate this fact. The surge-impedance of the line is assumed to be $Z_o = 300 \cdot \underline{15^\circ}$ ohms at the impressed frequency. Then the terminal angle at B is given by:

$$\tanh \theta' = \tanh \delta_B = \frac{Z_r}{Z_o} = \frac{600/\underline{33^\circ}}{300 \underline{15^\circ}} = 2.0/\underline{48^\circ}$$

Now entering the Chart XII_A of the atlas above referred to, with 2.0 as abscissa and 48° as ordinate on the rectilinear back-

FIG. 2.



Composite telephone circuit of central overhead section and terminal cable sections.

ground, we find at the required point the curved line of 0.3, and slightly beyond the intersection with the curve of $j\,0.75$. We can readily estimate, therefore, the value of θ' as $0.30 + j\,0.752$, as far as 3 significant digits. From this it follows that $\delta_A = 1.3 + j\,3.752$ and, at the midpoint P of the line, the position-angle $\delta_P = 0.8 + j\,2.252$ hyps.

We may apply the above principles to the case of a three-section composite telephone line like that shown in Fig. 2. Here an overhead line CD , 250 km. (155 miles) long, consisting of a pair of No. 10 A. W. G. (0.259 cm. diameter) at an interaxial distance of 1 foot, with 5 km. (3.1 miles) of standard No. 19 A. W. G. twisted-pair cable at each end. At A is impressed an alternating electromotive force of 2 volts, at 796ω ($\omega = 5000$ radians per second), the standard telephone frequency; while at F is an impedance of $1500/\underline{70^\circ}$ ohms. It is required to find the characteristics of the circuit, and the received current strength

at *F*. The following table gives the linear constants of the three line sections.

	Section 1 (<i>A-B</i>)	Section 2 (<i>C-D</i>)	Section 3 (<i>E-F</i>)
Section length, km.....	5.0	250.0	5.0
Linear resistance <i>r''</i> ohms per loop km.....	54.68	6.586	54.68
Linear inductance <i>l''</i> Hen- rys per loop km.....	0.6213×10^{-3}	2.284×10^{-3}	0.6213×10^{-3}
Linear capacitance <i>c''</i> Farads per loop km....	0.3355×10^{-7}	0.4982×10^{-7}	0.3355×10^{-7}
Linear leakance <i>g''</i> mhos per loop km.....	3.107×10^{-6}	0	3.107×10^{-6}
Hyperbolic angle at $\omega =$ 5000, hyps.....	$0.3324 + j \ 0.2199$	$1.171 + j \ 2.785$	$0.3324 + j \ 0.2199$
Surge-impedance per wire, ohms.....	$285.7 \angle 42^{\circ}.843$	$363.7 \angle 14^{\circ}.983$	$285.7 \angle 42^{\circ}.843$

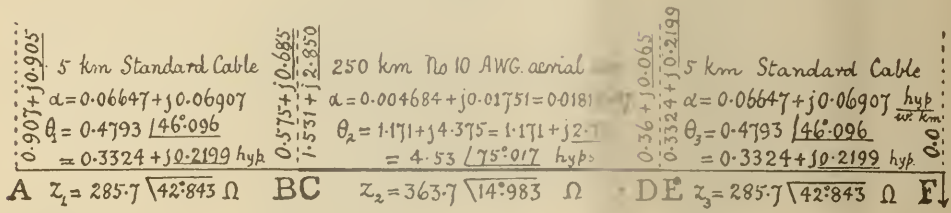
With the linear constants given in the table, we form the single line *AF* at the top of Fig. 3. We may then proceed to find the equivalent *Π* of this line, in either of two ways. One is indicated at successive stages in Fig. 3. The other is completely worked out, with the aid of hyperbolic charts, in Fig. 4. In each case we arrive at a *Π*-connection of three impedances *a f g g*, with about $1110/103^{\circ}$ in the line, and two terminal leaks, each of $2.35 \text{ millimho}/16^{\circ}.9$ to ground. This equivalent *Π* completely represents one wire of the composite loop-line *AF* at the frequency considered; so that if we connect 1 volt to the end *a* and $750/70^{\circ}$ ohms to ground from *f*, we shall have the same entering and leaving currents and potentials at *a* and *f* as on the actual line at *A* and *F* respectively; although along the actual line the conditions will be very different from those in the middle of the equivalent *Π*.

In Fig. 3, we commence by establishing the equivalent *Π* for each section, according to known rules.² Thus, each section of cable is represented by an architrave impedance of $136.2 + j13.13$ ohms, with a pillar leak at each end of $8.4 \times 10^4/87^{\circ}.743$ ohm. The three individual section-*Π*s are now connected in series and are to be reduced to a final single *Π* by successive steps. At *A'' B'' E'' F''* the three *Π*s are joined together, and adjacent pillar

² "The Application of Hyperbolic Functions to Electrical Engineering Problems," by A. E. Kennelly, University of London Press, 1911. (Chapter III.)

which is really a current lagging $360 - 103^\circ = 257^\circ$ behind the impressed electromotive force at A . But if we connect the end F to ground through an instrument of $50/70^\circ$ ohms impedance, this instrument is virtually shunted by the pillar leak of $426 \angle 16^\circ.9$

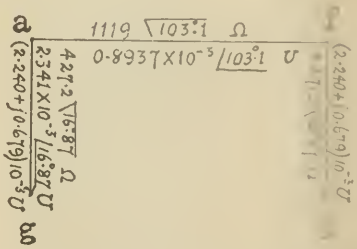
FIG. 4.



$$\delta_D = \tanh^{-1} \left(\frac{Z_3}{Z_2} \tanh \delta_E \right) = \tanh^{-1} \left(\frac{285.7 \angle 42.843}{363.7 \angle 14.983} \times 0.471 \angle 1.5 \right) = \tanh^{-1} (0.3703 \angle 13.64)$$
$$\delta_D = 0.36 + j0.065$$
$$\theta_2 = 1.171 + j2.785$$
$$\delta_C = 1.531 + j2.850$$
$$\delta_B = \tanh^{-1} \left(\frac{Z_2}{Z_1} \tanh \delta_C \right) = \tanh^{-1} \left(\frac{363.7 \angle 14.983}{285.7 \angle 42.843} \times 1.0 \angle 2.43 \right) = \tanh^{-1} (1.393 \angle 30.29)$$
$$\delta_B = 0.575 + j0.685$$
$$\theta_1 = 0.332 + j0.220$$
$$\delta_A = 0.907 + j0.905$$

$$\rho_n = Z_1 \sinh \delta_A \cdot \frac{\cosh \delta_C}{\cosh \delta_B} \cdot \frac{\cosh \delta_E}{\cosh \delta_D}$$
$$= Z_1 \sinh(0.907 + j0.905) \cdot \frac{\cosh(1.531 + j2.850)}{\cosh(0.575 + j0.685)} \cdot \frac{\cosh(0.332 + j0.220)}{\cosh(0.36 + j0.065)}$$
$$= 285.7 \angle 42.843 \times 1.434 \angle 83.9 \times \frac{2.263 \angle 255.3}{0.780 \angle 43.9} \times \frac{1.0 \angle 2.5}{1.0 \angle 2.1} = 1119 \angle 103.1 \Omega$$

$$Y_{Ag} = y_1 / \tanh \delta_A = 3.500 \times 10^{-3} \angle 42.843 / 1.368 \angle 5.6 = 2.541 \times 10^{-3} \angle 37.243 = (2.037 + j1.549) \times 10^{-3} \text{ } \Omega^{-1}$$
$$1/\rho_n = 0.8937 \times 10^{-5} \angle 103.1 \text{ } \Omega^{-1}$$
$$Y_{Ag} = (2.037 + j1.549) \times 10^{-3} \text{ } \Omega^{-1}$$
$$= (2.240 + j0.679) \times 10^{-3} \text{ } \Omega^{-1}$$
$$= 2.341 \times 10^{-3} \angle 16.87 \text{ } \Omega^{-1}$$



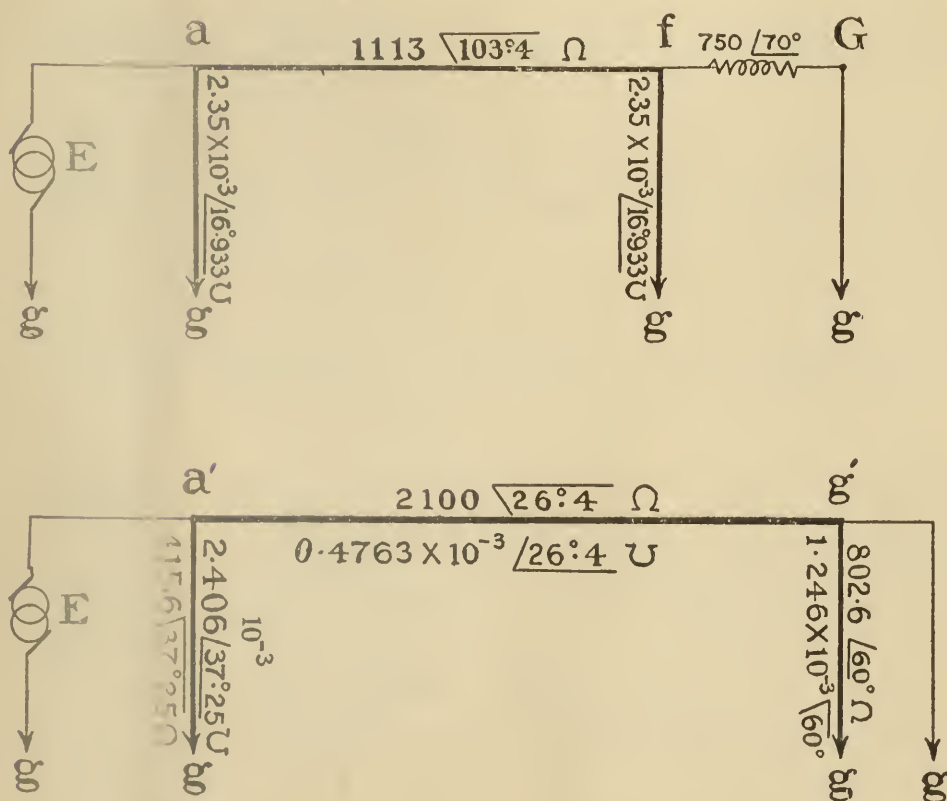
Full computation of hyperbolic Π for the three section composite line.

ohms; so that the effect of this shunt leak must be taken into account when finding the current through the instrument. In Fig. 5 this is done by substituting a Π for the T - $ifGg$; namely, $a' g' g g$. The architrave of this Π , which includes the receiving instru-

ment, is $2108 \angle 26^\circ.4$ ohms. If we ground the instrument, the current flowing through it to ground is $0.4763/26^\circ.4$ milliampère.

A shortcut to the same result, with the aid of charted hyperbolic functions, is indicated in Fig. 6. Here the position-angle of the section end F is $\delta_F = -0.132 + j0.781$ hyp.; i.e., a negative value of 0.132 hyperbolic radian and 0.781 of a circular quadrant. Three references have to be made to the charts of tangents. The formula for η then requires one reference to a chart of sines,

FIG. 5.



terminal load and the extension of the merger II to include it.

and seven successive references to charts of cosines. The multiplication calls for the use of the slide rule for the moduli, and simple addition for the arguments. The value of the pillar leak $g'g$ does not need to be determined, as the line is worked with G' grounded. The equivalent line impedance, including the receiving instrument is $2108 \angle 26^\circ.5$ ohms, and the received current from $1.0/0^\circ$ volt A is $0.4744/26^\circ.5$ milliampère in the instrument GG' .

The current and voltage at any point along the line are found in a few moments by formulas (3) or (4), which each call for

which is really a current lagging $360^\circ - 103^\circ = 257^\circ$ behind the impressed electromotive force at A . But if we connect the end F to ground through an instrument of $750/70^\circ$ ohms impedance, this instrument is virtually shunted by the pillar leak of $426 \angle 16^\circ.9$

FIG. 4.

5 km Standard Cable	250 km. No. 10 AWG. aerial copper	5 km Standard Cable
$\alpha = 0.06647 + j0.06907$	$\alpha = 0.004684 + j0.01751 = 0.01812 \angle 75^\circ.07$	$\alpha = 0.06647 + j0.06907$ hyp in km.
$\theta = 0.4793 \angle 46^\circ.096$	$\theta_2 = 1.171 + j4.375 = 1.171 + j2.785$	$\theta_3 = 0.4793 \angle 46^\circ.096$
$= 0.3324 + j0.2199$ hyp	$= 4.53 \angle 75^\circ.017$ hyps.	$= 0.3324 + j0.2199$ hyp
$A \quad Z_1 = 285.7 \angle 42^\circ.843 \quad \Omega$	$BC \quad Z_2 = 363.7 \angle 14^\circ.983 \quad \Omega$	$DE \quad Z_3 = 285.7 \angle 42^\circ.843 \quad \Omega \quad F$

$$\delta_D = \tanh^{-1} \left(\frac{Z_2}{Z_1} \tanh \delta_E \right) = \tanh^{-1} \left(\frac{285.7 \angle 42^\circ.843}{363.7 \angle 14^\circ.983} \times 0.4713 \angle 41^\circ.5 \right) = \tanh^{-1} (0.3703 \angle 13^\circ.64)$$

$$\delta_D = 0.36 + j0.065$$

$$\theta_2 = 1.171 + j2.785$$

$$\delta_C = 1.531 + j2.850$$

$$\delta_B = \tanh^{-1} \left(\frac{Z_2}{Z_1} \tanh \delta_C \right) = \tanh^{-1} \left(\frac{363.7 \angle 14^\circ.983}{285.7 \angle 42^\circ.843} \times 1.094 \angle 2^\circ.43 \right) = \tanh^{-1} (1.393 \angle 30^\circ.29)$$

$$\delta_B = 0.575 + j0.685$$

$$\theta_1 = 0.332 + j0.220$$

$$\delta_A = 0.907 + j0.905$$

$$\rho_n = Z_1 \sinh \delta_A \cdot \frac{\cosh \delta_C}{\cosh \delta_B} \cdot \frac{\cosh \delta_E}{\cosh \delta_D}$$

$$= Z_1 \sinh(0.907 + j0.905) \cdot \frac{\cosh(1.531 + j2.850)}{\cosh(0.575 + j0.685)} \cdot \frac{\cosh(0.3324 + j0.220)}{\cosh(0.36 + j0.065)}$$

$$= 285.7 \angle 42^\circ.843 \times 1.434 \angle 83^\circ.9 \times \frac{2.263 \angle 25^\circ.3}{0.780 \angle 43^\circ.9} \times \frac{1.00 \angle 6^\circ.5}{1.062 \angle 2^\circ.1} = 1119 \angle 103^\circ.1 \quad \Omega$$

$$Y_{A_g} = y_1 / \tanh \delta_A = 3.500 \times 10^{-3} \angle 42^\circ.843 / 1.368 \angle 5^\circ.6 = 2.559 \times 10^{-3} \angle 37^\circ.243 = (2.037 + j1.549) 10^{-3} \quad \mathcal{U}$$

$$1/\rho_n = 0.8937 \times 10^{-3} \angle 103^\circ.1 = (0.203 + j0.870) 10^{-3} \quad \mathcal{U}$$

$$Y_{A_g} = (2.240 + j0.679) 10^{-3} \quad \mathcal{U}$$

$$= 2.341 \times 10^{-3} \angle 16^\circ.87 \quad \mathcal{U}$$

a	1119 $\angle 103^\circ.1 \quad \Omega$	f
$(2.240 + j0.679) 10^{-3} \mathcal{U}$	$0.8937 \times 10^{-3} \angle 103^\circ.1 \quad \mathcal{U}$	$(2.240 + j0.679) 10^{-3} \mathcal{U}$
$2.341 \times 10^{-3} \angle 16^\circ.87 \quad \Omega$		$2.341 \times 10^{-3} \angle 16^\circ.87 \quad \Omega$
$4.272 \angle 16^\circ.87 \quad \Omega$		$4.272 \angle 16^\circ.87 \quad \Omega$
$2.341 \times 10^{-3} \angle 16^\circ.87 \quad \mathcal{U}$		$2.341 \times 10^{-3} \angle 16^\circ.87 \quad \mathcal{U}$
$(2.240 + j0.679) 10^{-3} \mathcal{U}$		$(2.240 + j0.679) 10^{-3} \mathcal{U}$
g		g

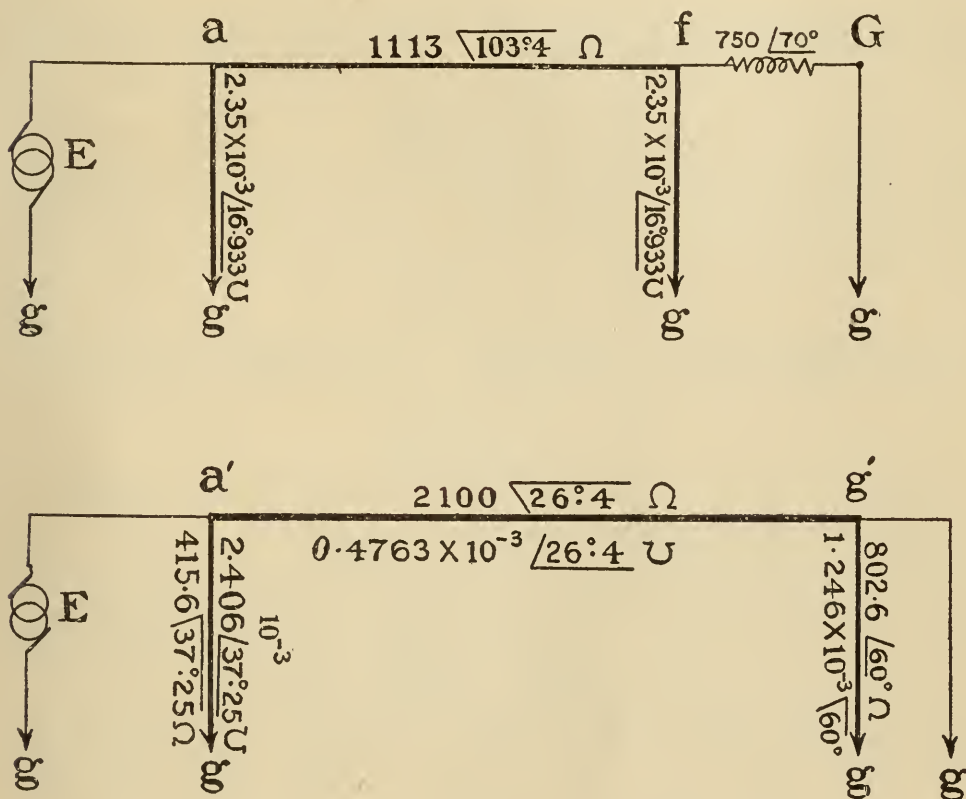
Full computation of hyperbolic Π for the three-section composite line.

ohms; so that the effect of this shunt leak must be taken into account when finding the current through the instrument. In Fig. 5 this is done by substituting a Π for the T — $afGg$; namely, $a' g' g g$. The architrave of this Π , which includes the receiving instru-

ment, is $2100 \angle 26^\circ.4$ ohms. If we ground the instrument, the current flowing through it to ground is $0.4763 / 26^\circ.4$ milliampère.

A short cut to the same result, with the aid of charted hyperbolic functions, is indicated in Fig. 6. Here the position-angle of the section-end F is $\delta_F = -0.132 + j0.781$ hyp.; i.e., a negative value of 0.132 hyperbolic radian and 0.781 of a circular quadrant. Three references have to be made to the charts of tangents. The formula for ρ_{11} then requires one reference to a chart of sines,

FIG. 5.



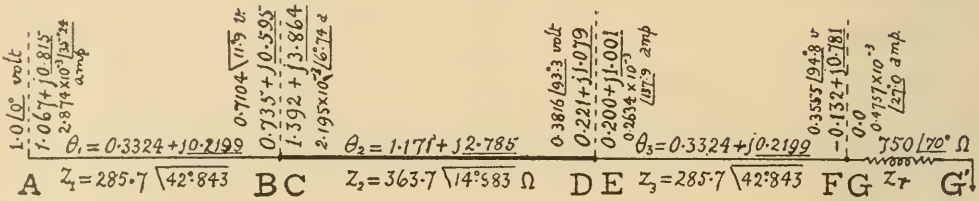
Terminal load and the extension of the merger II to include it.

and seven successive references to charts of cosines. The multiplication calls for the use of the slide rule for the moduli, and simple addition for the arguments. The value of the pillar leak $g'g$ does not need to be determined, as the line is worked with G' grounded. The equivalent line impedance, including the receiving instrument, is $2108 \angle 26^\circ.5$ ohms, and the received current from $1.0 / 0^\circ$ volt at A is $0.4744 / 26^\circ.5$ milliampère in the instrument GG' .

The current and voltage at any point along the line are found in a few moments by formulas (3) or (4), which each call for

two references to the charts. The values of current and voltage at the junctions have thus been supplied in Fig. 6.

FIG. 6.



$$\delta_F = \tanh^{-1} \left(\frac{Z_r}{Z_3} \right) = \tanh^{-1} \left(\frac{750 \angle 70^\circ}{285.7 \angle 42.843^\circ} \right) = \tanh^{-1} (2.625 \angle 112.843^\circ) = \tanh^{-1} (-1.019 + j2.420)$$

$$\delta_F = -0.132 + j0.781$$

$$\theta_3 = 0.332 + j0.220$$

$$\delta_E = 0.200 + j1.001$$

$$\delta_D = \tanh^{-1} \left(\frac{Z_2}{Z_3} \tanh \delta_E \right) = \tanh^{-1} \left(\frac{363.7 \angle 14.583^\circ}{285.7 \angle 42.843^\circ} \tanh (0.200 + j1.001) \right) = \tanh^{-1} (3.98 \angle 28.31^\circ)$$

$$\delta_D = 0.221 + j1.079$$

$$\theta_2 = 1.171 + j2.785$$

$$\delta_C = 1.392 + j3.864$$

$$\delta_B = \tanh^{-1} \left(\frac{Z_1}{Z_2} \tanh \delta_C \right) = \tanh^{-1} \left(\frac{285.7 \angle 42.843^\circ}{363.7 \angle 14.583^\circ} \tanh (1.392 + j3.864) \right) = \tanh^{-1} (1.137 \angle 24.86^\circ)$$

$$\delta_B = 0.735 + j0.595$$

$$\theta_1 = 0.332 + j0.220$$

$$\delta_A = 1.067 + j0.815$$

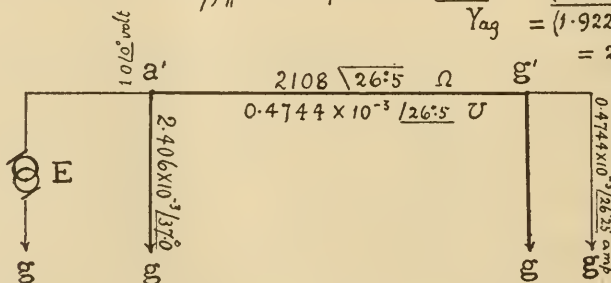
$$\begin{aligned} \rho_n &= Z_1 \sinh \delta_A \cdot \frac{\cosh \delta_C}{\cosh \delta_B} \cdot \frac{\cosh \delta_E}{\cosh \delta_D} \cdot \frac{\cosh \delta_G}{\cosh \delta_F} \\ &= 285.7 \angle 42.843^\circ \sinh (1.607 + j0.815) \frac{\cosh (1.392 + j3.864)}{\cosh (0.735 + j0.595)} \frac{\cosh (0.200 + j1.001)}{\cosh (0.221 + j1.079)} \frac{\cosh 0}{\cosh (-0.132 + j0.781)} \\ &= 285.7 \angle 42.843^\circ \frac{1.602 \angle 76.9^\circ}{1.002 \angle 40.3^\circ} \cdot \frac{2.125 \angle 11^\circ}{0.255 \angle 120.16^\circ} \cdot \frac{0.201 \angle 90.6^\circ}{0.363 \angle 20.3^\circ} \cdot \frac{1.0 \angle 0^\circ}{0.363 \angle 20.3^\circ} = 2108 \angle 26.5^\circ \Omega \end{aligned}$$

$$Y_{Ag} = y_1 / \tanh \delta_A = 3.500 \times 10^{-3} \angle 42.843^\circ / 1.218 \angle 7.6^\circ = 2.874 \times 10^{-3} \angle 35.243^\circ = (2.347 + j1.658) 10^{-3} \text{ U}$$

$$1/\rho_n = 0.4744 \times 10^{-3} \angle 26.5^\circ = (0.425 + j0.212) 10^{-3} \text{ U}$$

$$Y_{ag} = (1.922 + j1.446) 10^{-3} \text{ U}$$

$$= 2.406 \times 10^{-3} \angle 37.0^\circ$$



Full computation of hyperbolic Π for the three-section composite line including the terminal load.

It is evident that the same process may be extended to any number of sections forming a composite line. Rules have already been worked out for including readily in the hyperbolic- Π of a

composite line the effects of intermediate leaks or series loads along the line.³ Whereas, however, those rules were developed solely in connection with continuous-current circuits and real hyperbolic functions, the tables and charts of complex functions recently published now admit of the rules being applied with swiftness and ease to intricate alternating-current lines.

In undertaking any new departure in telephone-circuit design, involving new lengths of line, numbers of sections, or types of inserted apparatus, it has been customary to make up in the laboratory an artificial-line system, imitating the new conditions, and to test the same by trial. While in no way detracting from the value of such direct experimental methods, it ought to be possible to carry on an independent check by the computation of the resulting equivalent Π . Without hyperbolic functions, such computations are likely to be hopelessly difficult. With the aid of tables and charts of these functions, the process becomes relatively easy.

³ "The Equivalent Circuits of Composite Lines in the Steady State," by A. E. Kennelly, *Am. Ac. Arts and Sc.*, October, 1909.

Schilowsky Gyroscopic Monorail Car. ANON. (*Engineer*, cxvii, 106.)—A model of this car is at the Imperial College of Science, South Kensington, London, and is intended for demonstration purposes. A larger example of the system capable of accommodating six passengers is nearly completed. The gyroscopic axis is vertical and two pendulums are provided for automatically controlling the gyroscope. Thus, if the car lurches to the right, the left-hand pendulum pulls a cord and so puts a rack and pinion into mesh. This, in turn, gives such an action on the gyroscope as to call forth for it the desired righting torque and so balance the car.

Scandium. R. J. MEYER, A. WASSJUCHNOW, N. DRAPIER, and E. BODLÄNDER. (*Z. Anorg. Chem.*, lxxxvi, 257.)—Scandium oxide is best prepared from the oxide residues (0.3 per cent. Sc_2O_3) obtained in the manufacture of tungstic acid from wolframite from the Erzgebirge district of Saxony. For its preparation in quantity, free from thorium, the sodium carbonate method, or the ammonium tartrate method is preferred. A number of salts and double salts, complex fluorides, sulphates, and oxalates, are described, and it is pointed out that scandium differs from the other rare earth metals in its more pronounced electro-negative character, its salts showing a marked tendency to hydrolyze and to form stable complex double salts.

Paper and Paper Yarns. C. BEADLE and H. P. STEVENS. (*Chem. News*, cix, 242.)—Note on the dry and wet strengths of paper yarns. The strongest Swedish "kraft" papers used for the manufacture of paper yarns show a tensile breaking length in the machine direction of over 9 km.; papers made from Hedychium for the same purpose show over 10 km. When thoroughly wetted, the strength of the Swedish papers either disappears altogether or is reduced to a negligible quantity, the highest is 0.58 km.; the strength of wet Hedychium papers is still considerable, 1.58 km. The modern process of twisting paper yarns from the finished paper, subsequently moistened, results in a decrease of the dry strength, the yarns from the Swedish papers showing an average breaking length of 6.89 km., and those from Hedychium papers 7.37 km. On the other hand, the strength of thoroughly wet paper yarn is very much greater than the strength of the original paper in the wet state. Yarns from the Swedish papers showed a wet strength of 4.18 km. on the average, and yarns from Hedychium, 4.90 km. This increase of wet strength as between paper and paper yarn is due to the twisting of the strips. Yarn made in the old way, by twisting strips without drying and finishing the paper, gave inferior results, both wet and dry. In the manufacture of yarn, the general rule is to produce a paper of a substance of 40 to 44 grammes per square metre, and to vary the count of the yarn by varying the width of the strips.

Extra High Temperatures. ANON. (*Amer. Mach.*, xl, No. 26, 1106.)—A means of obtaining extra high temperatures from an electric arc is described in the "*Electrician*." The method consists of combining with an ordinary electric arc a jet of air or oxygen or an oxyacetylene or oxyhydrogen flame. The simplest form of the apparatus has a hollow carbon electrode through which a blast of oxygen or air can be blown. The metal plate to be heated forms the positive pole and the carbon electrode the negative. The arc is struck in the ordinary way and operated by a special mechanism with a hand feed. Several other arrangements may be used, some of which have separate pipes serving to project the oxyacetylene or oxyhydrogen flame on to the electric arc. It is stated that the effect of the oxygen burning inside the arc is to produce a temperature greatly in excess of that of the electric arc alone; also a similar effect is obtained when the oxyacetylene or oxyhydrogen flame burns in the same space as the electric arc.

A PHOTOGRAPHIC NULL METHOD FOR MEASURING ABSORPTION IN THE ULTRA-VIOLET.*

BY

W. R. HAM, Ph.D., R. B. FEHR, M.S., and R. E. BITNER, B.S.

THE primary object of this investigation was to develop a photographic method whereby the absorption of ultra-violet light by various absorbing media could be determined quantitatively.

It is a well-known fact that ultra-violet light (light of wave length less than $390\mu\mu$) may exert harmful physiological effects on the eye and skin, but just how much of this harm is to be ascribed to general energy radiation, and how much to specific radiation, is a matter that has by no means been settled. It is generally agreed that the extreme ultra-violet rays (those of wave length less than $300\mu\mu$) cause injury when in sufficient intensity. There are some who claim that the rays between 360 and $300\mu\mu$ also cause injury. Nutting states in Bureau of Standards Circular No. 28 that the 365th line of the mercury arc contributes 80 per cent. of the "fatigue effect" when this arc is used as a source of light. Whatever may be the extent of the extremely harmful region, there seems to be as yet no clinical evidence to show that the ultra-violet rays which get through glass (glass in general may be said to completely absorb all rays of wave length less than $300\mu\mu$ from any source) are injurious, unless in greater intensity than is to be found in any commercial light source. There are, however, many industrial processes requiring special protection of the eyes, on account of the excessive amount of ultra-violet radiation. It therefore becomes a matter of importance to know more of the physiological effects of radiation, and to be able to determine how much gets through a given sample of glass or other absorbing medium. Physiological data will no doubt be forthcoming in a few years. The present investigation deals with the other important question: How much ultra-violet light does a given sample of glass transmit?

* Communicated by Dr. Ham from the Engineering Experiment Station, The Pennsylvania State College, July, 1914.

OTHER INVESTIGATIONS.

A great deal of work has been done on ultra-violet light, both in Europe and in America, as shown by the bibliography at the end of this paper. However, very few quantitative investigations have been made. The quantitative researches that seem most important, from the standpoint of the present investigation, are those of Bell and Luckiesh. Dr. Louis Bell, by means of a thermopile and sensitive galvanometer, has obtained valuable data on the ultra-violet component of artificial light. M. Luckiesh has used a photographic method to obtain transmission curves of various kinds of glass; these curves seem to be the only ones on glass. Summarizing, it may be said that such quantitative work as has been done has been confined either to the somewhat troublesome and inconvenient methods of radiometry, or to the simpler and more convenient method of photography with its rather uncertain laws. It seemed desirable, therefore, to attempt to develop a photographic null method.

THEORY.

The absorption of light by a medium follows the exponential law; that is, the first layer absorbs a certain portion of the transmitted radiation, the next equal layer absorbs the same portion of what remains, and so on. This law is expressed by the following equation:

$$I = I_0 e^{-kd}$$

where

I_0 = initial intensity of light.

I = intensity of light after transmission.

k = coefficient of absorption.

d = thickness of absorbing medium in centimetres.

e = Napérian base.

This law applies, of course, only to homogeneous media and monochromatic radiation. The coefficient of absorption k varies in general with the wave length.

Radiation is not only partly absorbed in passing through a medium, but when it strikes a medium of different density, it is also partly reflected. Thus when light strikes glass, a small percentage is reflected at the air-glass surface, and also at the glass-air surface. This latter reflected light will be partly reflected back and forth between the faces of the glass, but since only a small

fraction (about 5 or 10 per cent.) is reflected at any one time, the two reflections mentioned first are the only ones that need be considered. When the glass is comparatively thin the amount of reflected radiation is quite large in comparison with the absorbed radiation, and the value of k calculated from the above formula will be considerably in error. The value of k thus calculated may be called the *apparent coefficient of absorption*. In order to determine the *true or absolute coefficient of absorption* two different thicknesses of the same kind of glass should be used as follows:

Let r_1 = fraction of incident radiation reflected at the air-glass surface.

Then $(1 - r_1)$ = fraction of incident radiation passing into the glass, and

$(1 - r_1)e^{-kd}$ = fraction of incident radiation reaching glass-air surface.

r_2 = fraction of radiation reflected at glass-air surface.

Then $(1 - r_2)(1 - r_1)e^{-kd}$ = fraction of incident radiation passing out of glass.

Therefore $I = mI_0e^{-kd}$

where $m = (1 - r_1)(1 - r_2)$, and is constant for varying thicknesses of the same kind of glass, neglecting multiple reflections within the glass itself.

Let d_1 and d_2 = the thickness in cm. of two samples of the same kind of glass.

I_1 and I_2 = the respective intensities of the radiation after passing through these samples.

$$\text{then } I_1 = mI_0 e^{-kd_1}$$

$$I_2 = mI_0 e^{-kd_2}$$

$$\text{Dividing } \frac{I_1}{I_2} = e^{-k(d_1 - d_2)}$$

$$\text{Log}_e \frac{I_1}{I_2} = -k(d_1 - d_2)$$

$$\text{Hence } k = \frac{\log_e \frac{I_1}{I_2}}{d_2 - d_1}$$

The measurement of d_1 and d_2 involves no difficulty, but the determination of I_1 and I_2 means that the intensity of ultra-violet must be measured quantitatively.

METHODS FOR MEASURING THE INTENSITY OF INVISIBLE RADIATION.

There are several means for determining the absorption of the ultra-violet light in a given medium. The radiometer, thermopile, and bolometer theoretically can give results with an uncertainty of 0.1 to 1.0 per cent. However, temperature changes,

air currents, magnetic disturbances, calibrations and general inconvenience of manipulation make it desirable in many cases to employ the photographic method, which, while not so sensitive, may give more positive and reliable results. The uncertainty of results in photographic spectrophotometry is usually stated to be about 5 per cent., or with special precautions, somewhat better. From the practical standpoint this degree of accuracy is quite sufficient. Furthermore, photography offers several distinct advantages over any other method:

1. Less adjustment is required than in any other method. As comparative exposures can be made within the short space of two minutes, the errors resulting from a change of conditions are very small.

2. Extremely faint lines can be detected and measured. This seems to be difficult to accomplish with other methods.

3. There can be no question as to the exact wave length that is being measured, for the spectral lines as they appear on a photographic plate are very definitely known.

4. The photographic plate gives a permanent record of the test.

THE METHOD EMPLOYED IN THIS INVESTIGATION.

On account of the many variables, such as temperature, time exposure and development, uniformity of emulsion, handling of the plate during development, etc., all of which enter into photography to a greater or less degree, it was at once decided to employ a null method. The intention was to interpose the absorbing medium in a beam of light of constant intensity and expose a photographic plate for a given length of time. The medium was then to be removed and the intensity reduced by a known amount. Immediately another exposure was to be made for the same length of time on the adjacent portion of the plate. Since these exposures could usually be made within two minutes there would hardly be any change of conditions during the process of obtaining the spectrograms, and since the exposures were to be made on the same plate, practically no errors would be introduced due to the emulsion and the development.

By making several exposures as above with various reduced intensities of the incident beam, a very close watch could be obtained between two adjacent images of the same spectral line,

and a fairly close estimate of the absorption obtained for that particular wave length. For example, if the effect produced by the original beam of light after passing through the medium were the same as the effect produced by the beam when striking the plate after a reduction of 30 per cent. in intensity, the absorption of the medium would be 30 per cent. for that particular wave length.¹

The problem now resolved itself into two parts: (1) to determine the equality of the densities of the two adjacent images on the photographic plate, and (2) to reduce the incident beam of light by a known amount.

With regard to the first part it might be in order to review briefly the characteristics of the photographic plate in so far as they affect the problem at hand. The density D of a photographic plate is a measure of the amount of metallic silver reduced in the film. If the ratio $\frac{I_i}{I_t}$ of the incident to the transmitted light is determined by means of a spectrophotometer or a microphotometer, the value of the density may be defined by the formula,—

$$D = \log_{10} \frac{I_i}{I_t}$$

If the densities of the plates exposed for equal lengths of time be plotted against the logarithms of the incident intensities of light, the relations shown in Fig. 1 will in general hold.

The curve is seen to consist of three distinct parts: An initial period ab during which the density increases very slowly with increase of intensity (under exposure); an intermediate period bc where the relation is approximately linear (correct exposure); and a final period cd where increase of intensity causes but slight increase of density (over exposure). The straight-line portion of the characteristic curve has been made use of in most of the quantitative photographic work up to the present time. It means that the so-called scale of gradation should be determined for each plate that is used for making comparative exposures. Other-

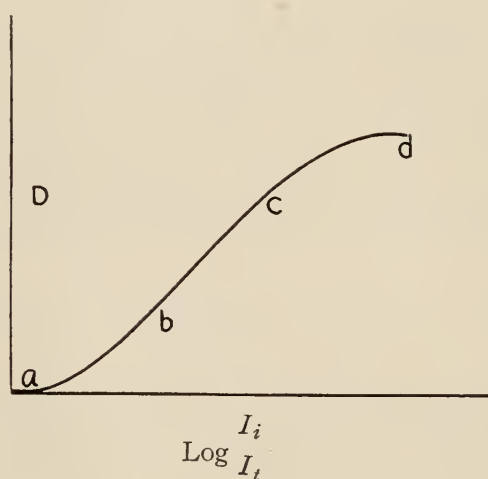
¹ Since the completion of this work the writer's attention has been called to an article appearing in *Comptes Rendus*, December, 1913, page 1065, where G. Ribaud describes a photographic null method for determining the absorption of ultra-violet by bromine vapor. For reducing the intensity of the incident beam of light he used two nicols.

wise errors due to development and non-uniformity of plates would be introduced. Such a procedure is necessarily long and tedious. In the balanced or null method, however, only a qualitative determination of this range of gradation need be made in order that the variation in density may be as great as possible for a given variation in intensity.

The equality of two adjacent images can thus be more easily judged. It is important to note that long development magnifies the range of densities corresponding to a given range of incident intensities.

Several different kinds of dry plate have been used in photo-

FIG. 1.



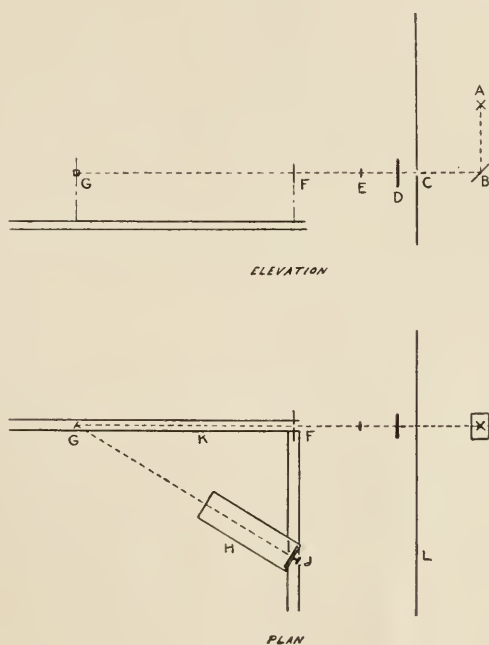
graphic photometry. The most commonly used are Seed's Gilt Edge 23, 26, and 30. For the work of the present investigation, No. 30 was found to be the most satisfactory; it is quite slow in action and is not affected above the *D* line. For work in the visible spectrum the Cramer Tri-Color plate was used. The Wratten Pan-Chromatic and M plates are also recommended. These pan-chromatic plates are ordinary plates which have been treated with certain dyes called sensitizers.

Ultra-violet light acts chiefly on the surface of the plate, while the visible light acts more evenly throughout the layer. In any case it is best to use a metol-hydro-quinone developer, which is noted for its action on the whole emulsion at once, depositing black silver throughout the layer, rather than only on the surface as in the case of other developers.

OPTICAL ARRANGEMENTS.

Now in order to study the absorption of definite wave lengths, it is necessary to have a constant source of ultra-violet light, and to disperse a beam of this light into its spectrum. Furthermore, the optical system must be as transparent as possible to ultra-violet light. This means that only fluorite or quartz lenses and prisms can be used. There are two ways of obtaining the spectrum for photographic processes. The first one is to use a spectrograph with its quartz prism. The instrument is very compact and

FIG. 2.



Arrangement of apparatus.

easy to manipulate. However, the Rowland concave grating method offers several distinct advantages. In the first place it gives greater dispersion and in the second place the distances between lines as measured on the plate are proportional to the differences in wave length of these lines.

For these reasons it was decided to use the concave grating method. The arrangement of apparatus is shown in Fig. 2, which is drawn to scale. *A* is the source of ultra-violet, namely, a 220-volt quartz mercury lamp, which was found to operate with great constancy after twenty minutes; *B* is a speculum metal

plane mirror for directing the beam of light horizontally. Speculum metal does not reflect the extreme ultra-violet very well, but as glass absorbs this extreme radiation totally, this failing was of no consequence. *L* is a wooden partition between the lamp compartment and the room containing the grating. *C* is a small hole in this partition, which contains an ordinary camera shutter with operating bulb. By this arrangement and a stop watch the time of exposure could be accurately observed within one-fifth of a second. *D* is a holder for the absorbing medium. *E* is a $1\frac{1}{4}$ inch diameter quartz lens with a principal focal length of 8 inches. By this means the image of the quartz burner could be sharply focused on the adjustable slit *F*. *K* is the usual track for maintaining the system in focus. *G* is a Rowland concave grating 3.3 cm. long by 2.2 cm. wide. The number of lines per inch is approximately 12,380 and the radius of curvature 1 meter. *H* is the camera box, *I* the photographic plate, in front of which is a partition with a horizontal slit $\frac{1}{2}$ cm. high for the purpose of limiting the height of the spectral lines; and *J* is a slow-motion screw for the final adjustment of the focus.

THE ABSORBING SCREENS.

The second part of the problem, namely, reducing the intensity of the incident beam of light by a known amount, involved a little difficulty. The intensity could not be altered by varying the distance from the source, nor could an iris diaphragm be used on account of the resulting unequal illumination of the grating. The simplest and, at the same time, the most positive means of reducing the intensity was to interpose a square-woven wire screen in the beam of light. The resulting integral effect of light thus reduced in intensity was tested out in a preliminary way by using ordinary wire gauze sieves. The results were so encouraging that it was decided to make up a set of these screens giving a range in transmission of from 5 to 95 per cent. Upon consulting manufacturers' catalogues, it was found that the maximum per cent. transmission that could be obtained in any such screen was about 75, and the minimum about 20. A large assortment of samples of brass and copper wire gauze was obtained and transmissions roughly determined on a Lummer-Brodhum photometer bar. It was thus found necessary to make up special screens for trans-

missions below 20 per cent. and also for 70, 80, and 90 per cent. The low transmission screens were easily made by combining screens, but the high transmission screens required fine wire to be carefully spaced and soldered on a rigid frame. All the available gauzes were also soldered on a brass ring two inches in diameter in order to insure flatness and to facilitate handling. The absorptions of these screens were then very carefully obtained on the photometer bar. The results are shown in Table I.

TABLE I.

MESHES PER INCH.	PER CENT. TRANSMISSION.
Combination of screens	3.06
Combination of screens	9.13
100	19.2
30	22.8
140	29.9
50	33.5
80	36.0
40	38.6
20	47.2
10	53.0
24	60.2
10	71.4
10	80.1
10	91.6

The reason that screens of the same mesh did not give the same per cent. transmission is of course because of the different diameters of the wire. It is best to have the number of meshes per inch 20 or over, in order to give a better integral effect. Preliminary tests showed that, in order to insure uniform density of the image on the plate, it was best to incline the wires 15 to 30 degrees from the vertical (keeping the screen always perpendicular to the beam of light), otherwise it was often possible to observe streaks on the images. It is also desirable, in combining two or more screens, to place the screens some distance apart.

DESCRIPTION OF THE TESTS.

Preliminary Tests.—The mirror and quartz lens were adjusted so as to give a vertical image (about 3 mm. wide) of the quartz tube on slit *F*. The grating was then adjusted by means of slow-motion screws to give uniform illumination of the spectral

lines on a ground glass at I . To secure the final adjustment of the images of the spectral lines the slit F was first moved on the track K to give approximate focus, the final focus being obtained by means of the slow-motion screw J .

Photographs were taken using a slit width of 0.10 mm. for the purpose of testing the adjustment of the mounting. The results showed good optical arrangements, but in the case of exposures of over 30 seconds there seemed to be a faint continuous spectrum (see Plate IV)² which apparently was not due to dispersion but to light reflected from the bright parts of the grating as well as from grating lines themselves. Black paper fixed over the grating fixtures eliminated a considerable part of this stray light, but not all. However, this trouble was of no great consequence.

In order to map the spectrum the distance between known lines on the plate were carefully measured. The mean of several measurements showed that each centimetre was equivalent to $20.02\mu\mu$. With the aid of Table II, which was compiled from the

TABLE II.
ARC SPECTRUM LINES OF MERCURY.

Wave Lengths in $\mu\mu$.

709.23	404.67	292.54
708.24	398.40	289.36
690.81	390.65	275.98
671.66	366.35	275.29
623.46	366.29	269.89
615.26	365.48	265.54
612.37	365.03	265.38
607.30	339.05	265.22
588.91	334.15	257.63
579.05	313.19	253.57
576.96	313.16	253.49
546.07	312.58	248.39
491.64	302.75	248.28
435.86	302.56	248.21
434.76	302.34	246.41
407.80	302.15	244.69
.....	295.74	239.94
.....	.....	237.84
.....	.....	230.27

² In the appendix will be found a number of typical spectrograms.

latest data, it was then a very simple matter to identify any line on a spectrogram.

A large number of spectrograms were taken in order to obtain the absorption of various samples of glass qualitatively; that is, to determine the minimum wave length that could get through. It was found that in most cases an exposure of five or ten seconds was sufficient to bring out nearly all the lines, but in many instances it was necessary to expose for 60 or even 120 seconds in order to bring out the minimum line very faintly.

This is a point that does not seem to have been greatly emphasized by other workers in this field, and is probably the reason why so many glasses are said to be better than they are actually. Another point to be looked out for in the matter of obtaining the minimum wave length transmitted, is the proper width of slit. With a slit width of 1 mm. the excessive stray light at long exposures obliterated any faint lines that would show with smaller slit widths. In order to secure the best results the slit width should never be more than about 0.3 mm. when dealing with very faint lines.

Absorption Tests.—For making the quantitative absorption tests it was decided to use some ordinary plate glass. A dozen pieces (2 inches x 4 inches) of such glass (marked “American”) were cut from the same plate in order to insure uniformity of test specimen in case of breakage; also to insure homogeneity in the case of varying thickness.

The receipt used in making this glass was as follows:

Sand (Ottawa)	100
Salt Cake	38
Lime Stone	28
Carbon	2.5

The transmission of a single thickness of this glass in the visible spectrum of a tungsten lamp burning at 1.25 watts per candle was found on the photometer bar to be 90.2 per cent.

First of all the glass was tested for the minimum wave length transmitted (see Plate XI). The absorption of the various wave lengths was obtained in the following way:

The initial intensity of the beam of light was reduced either by throwing the image off the slit, or by interposing an absorbing screen. As the intensity was kept constant throughout any given

test, no further account need be taken of this reduction in intensity except as a matter of record. It was found necessary to reduce the intensity in order to increase the time of exposure in the very strong lines to 5 or 10 seconds, so as to minimize the error due to observing the time of exposure.

Next the camera box *H* was slid along the track until the desired part of the spectrum was thrown on the photographic plate. The test specimen of glass was interposed in the beam of light and a series of exposures of varying time with one mm. slit was made in order to determine for each line the correct time of exposure to give a rather faint image of the line so that any change in intensity would cause considerable change in density.

After a study of the proper time of exposure had been made for each important line, a series of spectrograms were taken, keeping the time of exposure constant, and substituting for the test specimen a series of absorbing screens in order to determine approximately the range of absorption for each prominent wave length. When the glass was interposed in the beam of light care was always taken that the path of the reflected beam coincided with the path of the incident beam so as to be sure that the image on the slit was not displaced.

With a knowledge of the proper time of exposure and the approximate absorption for each wave length it was then merely a matter of taking some final spectrograms of the glass and absorbing screens.

The above procedure was carried out for a single thickness of "American" glass, and then for a triple thickness obtained by clamping three single thicknesses together. In order to eliminate reflection at the inner faces, a few drops of chloral hydrate in a solution of glycerine was placed between the glasses. This solution having practically the same index of refraction as ordinary glass, eliminated the effect of the inner faces and gave a practically homogeneous medium.

RESULTS OF TESTS.

Table III gives the results of the absorption tests on "American" plate glass. The first horizontal line in each set of data gives the wave length; the vertical columns, the range of per cent. of transmission (the minimum always being given in the

first space) and the last horizontal column in each set, the per cent. transmissions as estimated by the eye from the final tests. At first, a binocular microscope was used, but this arrangement offered so little improvement that it was abandoned in favor of the naked eye.

TABLE III.
RESULTS OF TESTS—OBSERVED DATA. SINGLE THICKNESS OF GLASS.

No. Plate	492	436	408	405	391	365	334	313	302
41	80-100	.....	80-100	50-100	39-53	.....	.....
44	min.	0
49	80-100	80-100	80-100	80-100	60-100	39-47	.....	.....
52	-92	-92	-92	.....	-92	.....	.....	.....
53	-92	-92	-92	-92	-92	.....	.....	.....
54	80-	80-	80-	.....	71-80	.....	.....	.....
55	80-92	.....	80-92	.....	71-80	.....	.....	.....
56	0.3-3.0	0
62	80-92	80-92	80-92	80-92	71-92	39-47	.....	.....
Est'd.	88	88	86	86	77	46	1.5	0

Triple Thickness of Glass.

66	.....	47-80	60-71	47-80	.....	47-71	.....	.....	.....
71	-80	60-80	60-80	60-80	.....	53-60	9-20	.....	.....
72	80-85	80-	70-80	80-	-70	53-60	.....	.....	.....
Est'd.	80	80	77	80	67	57	12	.....	.....

TABLE IV.
CALCULATED RESULTS.

Wave Length	I_1	I_2	k_1	k_2	k	$1-m$
320	.013	.077	4.45	7.53	2.80	0.800
325	.035	.170	.....	.....	2.48	.....
330	.075	.315	2.65	3.38	2.25	.320
335	.135	.482	2.04	2.13	1.96	.....
340	.218	.565	1.55	1.68	1.50	.060
350	.367	.671	1.02	1.17	.947	.....
360	.490	.743	.728	0.872	.654	.071
380	.675	.832	.402	0.540	.328	.069
400	.757	.868	.284	0.416	.220	.061
420	.790	.878	.240	0.378	.164	.071
440	.800	.880	.228	.374	.150	.074

The plotted transmissions are shown in Fig. 3.
In Table IV are shown the calculated results derived by using the values of I_1 and I_2 (obtained from these transmission curves) in the formulæ on page 313.

FIG. 3.

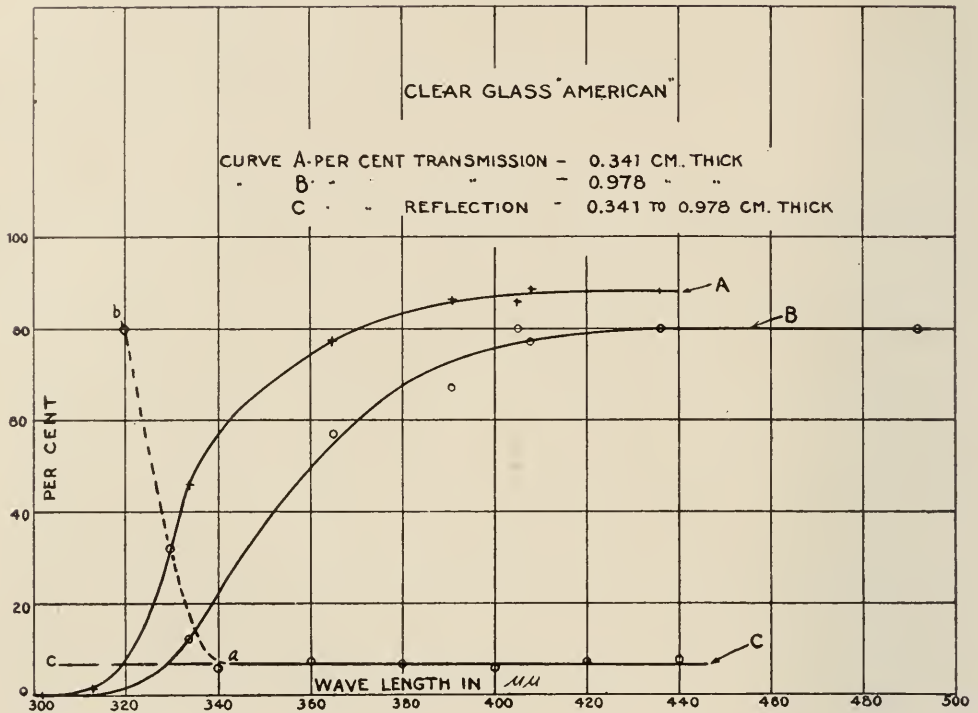
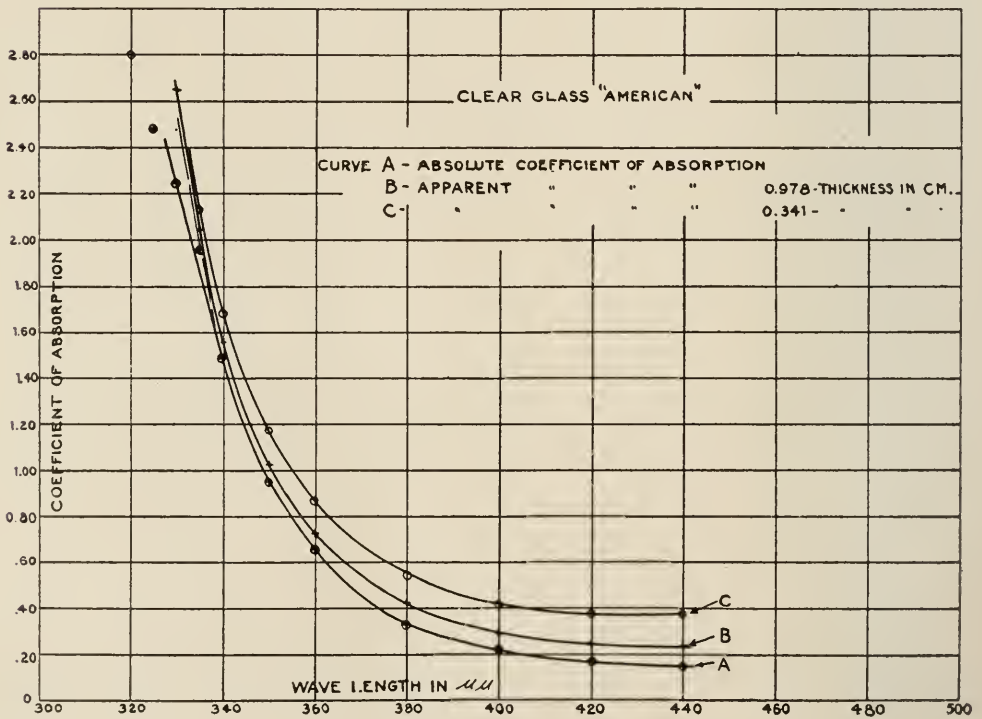


FIG. 4.



$$k = \frac{\log_e \frac{I_2}{I_1}}{d_1 - d_2} \text{ (Absolute coefficient of absorption).}$$

$$k_1 = \frac{\log_e \frac{I_0}{I_1}}{d_1} \text{ (Apparent coefficient for thick glass).}$$

$$k_2 = \frac{\log_e \frac{I_0}{I_2}}{d_2} \text{ (Apparent coefficient for thin glass).}$$

$$\log_e m = \log_e \frac{I_1}{I_0} + kd_1 \quad \text{(Where } m \text{ equals the fraction of radiation remaining, subtracting amount lost due to reflections).}$$

In these formulæ I_0 is taken as unity. Fig. 4 shows the plotted calculated values of the absorption coefficients and curve C (Fig. 3) shows the plotted values of the per cent. reflection.

DISCUSSION OF RESULTS.

As was to be expected, from the previous theoretical considerations, the apparent coefficient of absorption for the thin glass was greater than for the thick glass, and at very high absorptions these coefficient curves appeared to merge into each other. The broken part of the curve A will be referred to below.

The reflection curve C (Fig. 3) is dotted below wave lengths 340 on account of the fact that the relative values of the observed transmissions in this region are probably in great error. For example, it was found that the per cent. of transmission in the thin glass for the 313th line lay between 0.3 and 3.00 and was roughly estimated at 1.5. In the case of thick glass this line was so faint that no estimate could be obtained. Consequently, the ratio of the transmissions was indeterminate at this point, and not very accurate at other points of this end of the transmission curves.

Now the reflection curve is practically a straight line throughout the part of the spectrum that was measured quite accurately for absorption. This fact showed that there was no selective reflection in this region, and since there are no data to show that glass reflects selectively any radiation which it can transmit, the straight part of this reflection curve was extrapolated as shown by the broken line ac . With the constant value .068 for $(1-m)$, and therefore 0.932 for m , the absolute coefficients k were calculated from the following formulæ:

$$k = \frac{\log_e m - \log_e \frac{I_1}{I_0}}{d_1}$$

$$k = \frac{\log_e m - \log_e \frac{I_2}{I_0}}{d_2}$$

These corrected values of k are shown in Table V. Since both I_1 and I_2 were considerably in error, two different values of k were found, one for each thickness of glass. Furthermore, this correction was obtained by correcting only the m term of the above formulæ. Hence the results would still be in error, but by taking the averages the doubtful end of the absolute coefficient of absorption curve could be better drawn in as shown by the broken lines in Fig. 4.

TABLE V.
CORRECTED VALUES OF k .

Wave Length	k (0.341 cm.)	k (6.978 cm.)	Average k
320	7.32	4.38	5.85
330	3.18	2.58	2.88
335	1.93	1.97	1.95
340	1.47	1.48	1.48

As to the accuracy of the observed data, it can be stated that the eye was able to detect without difficulty a 10 per cent. change in the intensity; and that, therefore, with sufficient screens the estimated transmissions were in error not more than 5 per cent. It was very likely that a microphotometer would decrease this figure considerably. As the source of the ultra-violet did not fluctuate more than 1 per cent. within the space of three minutes, and as the time of exposure was correct, within 1 per cent., these errors were comparatively too small to have any effect on the results.

SUMMARY.

1. The photographic null method as described gives coefficients of absorptions easily to within 5 per cent.

2. To secure the best results the intensity of the transmitted beam of light and the time of exposure should be such as to give a light gray image on the photographic plate.

3. The time of exposure should be 10 seconds or over.
4. No shadows of the wires of the screens should appear on the grating.
5. In working with very faint lines the slit width should not be more than 0.3 mm. nor less than 0.2 mm.

In conclusion, the authors wish to express appreciation to Dr. J. P. Jackson, Commissioner of Labor of Pennsylvania, and Dean of the School of Engineering of The Pennsylvania State College, for aid given in starting these experiments and interest taken in the results obtained.

APPENDIX.

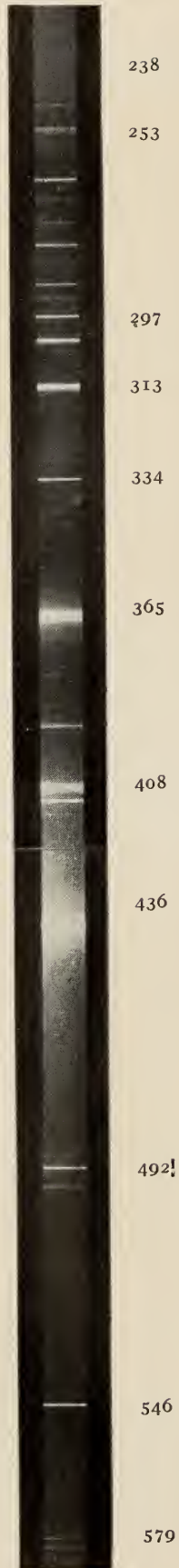
In this appendix are shown a number of typical spectrograms (Plates XIII, XIV, and XV) for obtaining absorptions quantitatively, as well as several spectrograms for illustrating the transparency of various colored glasses to ultra-violet light. It must be remembered that no final conclusions can be drawn from the prints, for it is practically impossible to reproduce the faintest lines of the negative. In all cases the results were obtained from the photographic plate and never from a print.

Plate I is a spectrogram of the mercury arc spectrum showing the principal lines (in $\mu\mu$) for reference. This plate was obtained from the quartz mercury lamp without its glass globe, and wherever "quartz" is mentioned as the absorbing medium, it means that the spectrogram was obtained from the bare mercury arc; *i.e.*, with the quartz tube as the only absorbing medium.

Plates II and XI show how important it is to increase the time of exposure until no more lines appear on the spectrogram. With the apparatus used it was found that an exposure of 120 seconds was sufficiently long to bring out the line of minimum wave length in all of the glasses tested, whether high or low in the transmission of visible light. In most cases, however, it was found that exposures of 30 or even 10 seconds were quite long enough.

For the sake of comparison the times of exposure in Plates XII *a*, *b*, *c*, and *d* were all 120 seconds. The data giving the per cent. transmission for tungsten light at 1.25 watts per candle was readily obtained by means of a flicker photometer. In looking over the data obtained, in regard to the minimum wave length

PLATE I.



Mercury arc spectrum (wave lengths in $\mu\mu$).

PLATE II.



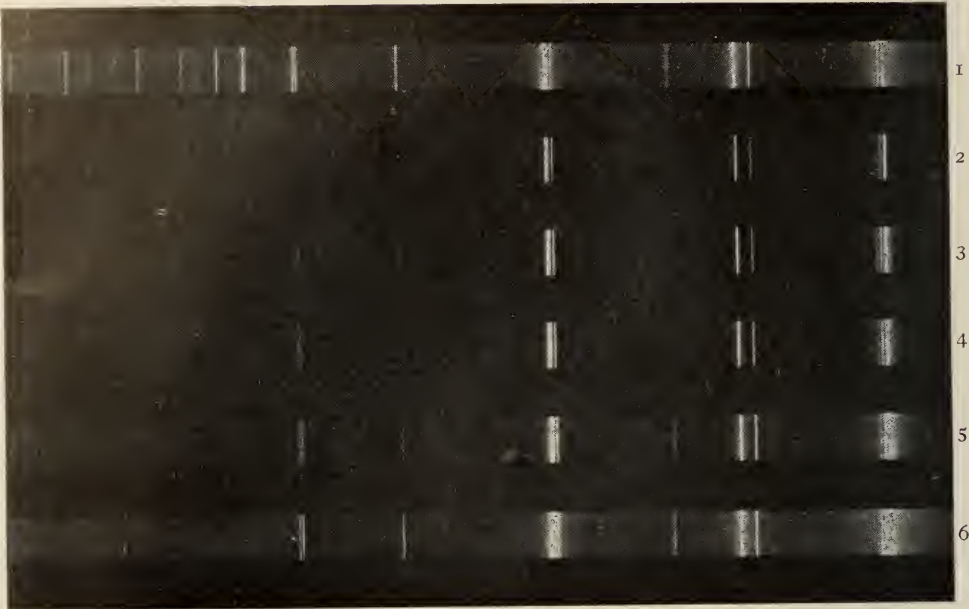
- | | |
|------------------------|--------------|
| 1. Quartz..... | 10 seconds. |
| 2. "Nultra" glass..... | 10 seconds. |
| 3. "Nultra" glass..... | 20 seconds. |
| 4. "Nultra" glass..... | 30 seconds. |
| 5. "Nultra" glass..... | 60 seconds. |
| 6. "Nultra" glass..... | 120 seconds. |

PLATE III.



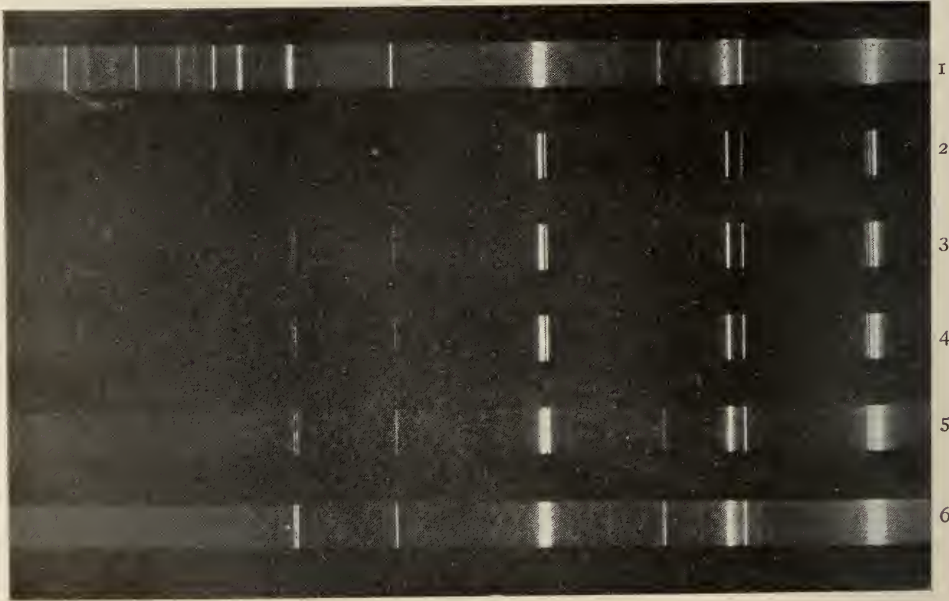
- | | |
|------------------------|--------------|
| 1. Quartz..... | 10 seconds. |
| 2. "Euphos" glass..... | 10 seconds. |
| 3. "Euphos" glass..... | 20 seconds. |
| 4. "Euphos" glass..... | 30 seconds. |
| 5. "Euphos" glass..... | 60 seconds. |
| 6. "Euphos" glass..... | 120 seconds. |

PLATE IV.



- | | |
|-----------------------|--------------|
| 1. Quartz..... | 30 seconds. |
| 2. "Clear globe"..... | 10 seconds. |
| 3. "Clear globe"..... | 20 seconds. |
| 4. "Clear globe"..... | 30 seconds. |
| 5. "Clear globe"..... | 60 seconds. |
| 6. "Clear globe"..... | 120 seconds. |

PLATE V.



- | | |
|----------------------------|--------------|
| 1. Quartz..... | 30 seconds. |
| 2. "Opalescent globe"..... | 20 seconds. |
| 3. "Opalescent globe"..... | 30 seconds. |
| 4. "Opalescent globe"..... | 60 seconds. |
| 5. "Opalescent globe"..... | 120 seconds. |

PLATE VI.



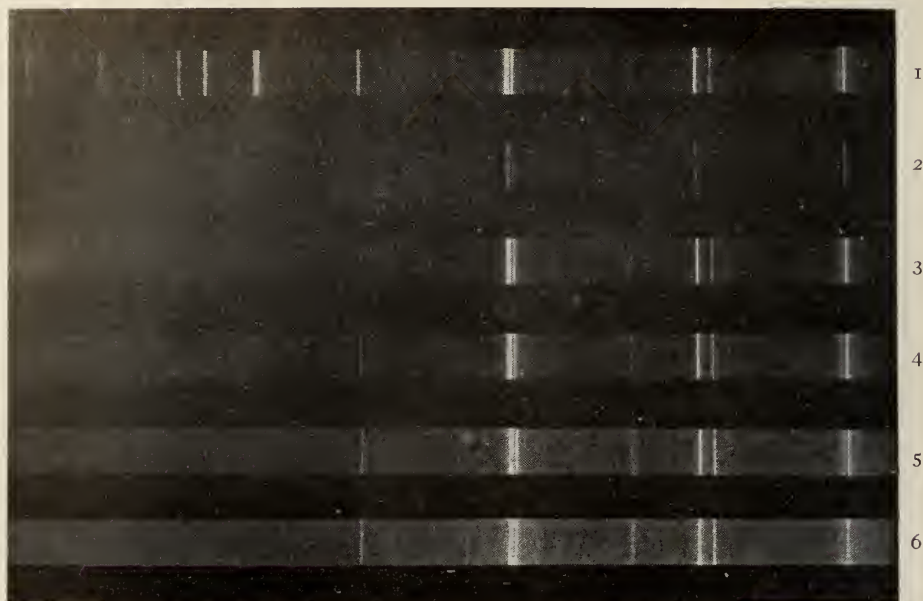
- | | |
|-----------------------------|--------------|
| 1. Quartz..... | 20 seconds. |
| 2. Orange yellow glass..... | 2 seconds. |
| 3. Orange yellow glass..... | 10 seconds. |
| 4. Orange yellow glass..... | 30 seconds. |
| 5. Orange yellow glass..... | 60 seconds. |
| 6. Orange yellow glass..... | 120 seconds. |

PLATE VII.



- | | |
|---------------------------------|--------------|
| 1. Quartz..... | 20 seconds. |
| 2. Very light yellow glass..... | 2 seconds. |
| 3. Very light yellow glass..... | 10 seconds. |
| 4. Very light yellow glass..... | 30 seconds. |
| 5. Very light yellow glass..... | 60 seconds. |
| 6. Very light yellow glass..... | 120 seconds. |

PLATE VIII.



- | | |
|--------------------|--------------|
| 1. Quartz..... | 20 seconds. |
| 2. Blue glass..... | 2 seconds. |
| 3. Blue glass..... | 30 seconds. |
| 4. Blue glass..... | 60 seconds. |
| 5. Blue glass..... | 120 seconds. |
| 6. Blue glass..... | 240 seconds. |

PLATE IX.



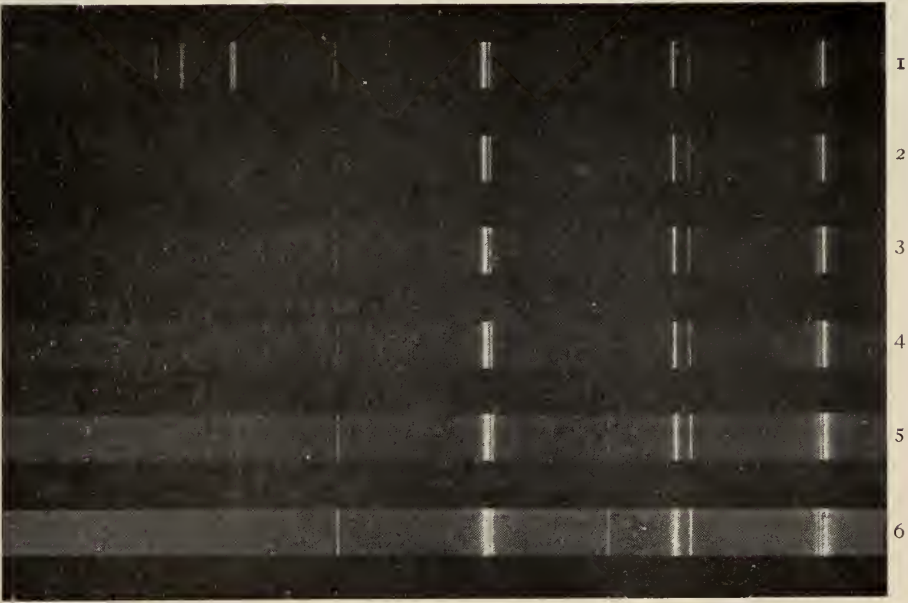
- | | |
|--------------------------|--------------|
| 1. Quartz..... | 20 seconds. |
| 2. Faint pink glass..... | 2 seconds. |
| 3. Faint pink glass..... | 30 seconds. |
| 4. Faint pink glass..... | 60 seconds. |
| 5. Faint pink glass..... | 120 seconds. |

PLATE X.



- | | |
|--------------------|--------------|
| 1. Quartz..... | 20 seconds. |
| 2. Pink glass..... | 2 seconds. |
| 3. Pink glass..... | 30 seconds. |
| 4. Pink glass..... | 60 seconds. |
| 5. Pink glass..... | 120 seconds. |

PLATE XI.



- | | |
|--------------------------------|--------------|
| 1. Quartz..... | 10 seconds. |
| 2. "American" clear glass..... | 10 seconds. |
| 3. "American" clear glass..... | 20 seconds. |
| 4. "American" clear glass..... | 30 seconds. |
| 5. "American" clear glass..... | 60 seconds. |
| 6. "American" clear glass..... | 120 seconds. |

transmitted, some very interesting results may be noted. For example, the faint pink of No. 4 transmits practically as much ultra-violet as the light blue of No. 20. Since both glasses have approximately equal transmissions for visible light, it was to be expected that the one nearer the red end of the spectrum would

PLATE XII *a*.

No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum Line. $\mu\mu$.
1.	Quartz.....	...	...
2.	Very deep red glass.....	4.1	...
3.	Red glass.....	17.8	...
4.	Faint pink.....	50.1	313
5.	Orange yellow.....	38.3	334
6.	Yellow.....	54.3	334
7.	Yellow ("Noviol").....	78.0	546
8.	Very light yellow.....	78.8	313

cut off more ultra-violet, but this case clearly shows that no dependence may be placed on the color of the glass. Again, Nos. 7 and 8 of very nearly the same shade of yellow show widely different degrees of transmission of ultra-violet, the "Noviol" not transmitting even all of the visible wave lengths, while the other light yellow glass transmits as far down as the 313th line.

“Euphos” glass No. 11 cuts off the ultra-violet very sharply at 405, but “Nultra” glass appears to be better from a practical standpoint, for it barely transmits the 365th line (less than 1 per cent. by actual test) and absorbs only 15 per cent. of the visible light. The most remarkable glass of all is the orange-yellow of

PLATE XII b.



No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum line. μμ
9.	Faint yellow (“Nultra”).	85.0	365
10.	Faint yellow.	84.3	313
11.	Yellow green (“Euphos”).	72.0	405
12.	Yellow green.	71.6	365
13.	Faint yellow green.	82.5	302
14.	Very deep green.	2.6	405
15.	Dark green.	5.0	365
16.	Green.	52.0	334

No. 5 (also see Plate VI), which appears to transmit selectively between 334 and 405, although its greatest transmission is at the other end of the spectrum.

Such examples as those cited above show very conclusively that the protective property of a glass cannot be judged by mere inspection.

The only safe conclusion in regard to the transmission of glasses for ultra-violet light is that there does not seem to be any glass which transmits below the 302th line, and which does not therefore cut out what is generally conceded to be the extremely harmful rays. However, until more conclusive data are

PLATE XII c.



No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum line. $\mu\mu$
17.	Quartz.....	....	...
18.	Dark blue violet glass.....	2.5	334
19.	Blue.....	8.3	334
20.	Light blue ("Tungsten").....	46.1	302
21.	Reddish purple.....	23.2	334
22.	Dark flesh color.....	44.3	334

obtained on this matter of the injurious ultra-violet light, every protective glass should be tested out at least qualitatively in the manner previously described, and those glasses which do not absorb almost completely the 365th line should be rejected.

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PLATE XII *d*.



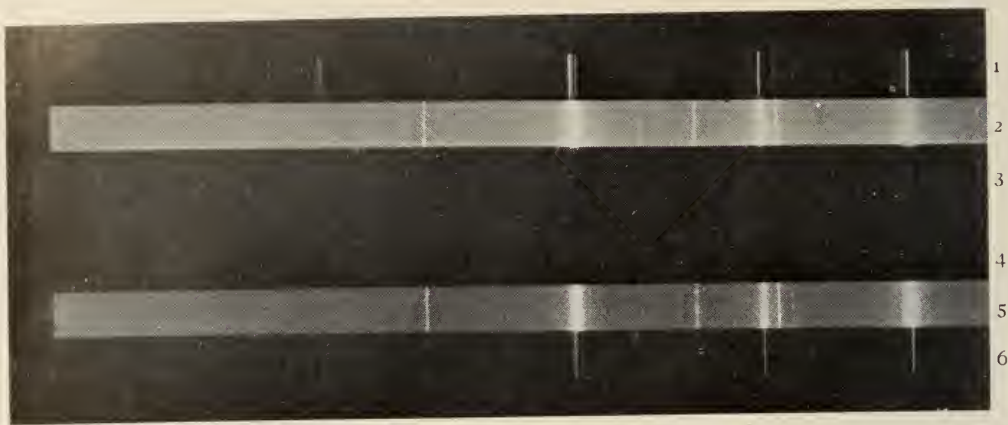
No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum line. $\mu\mu$
23.	Quartz.....	....	....
24.	Light flesh color.....	73.8	334
25.	Dark gray.....	15.3	334
26.	Medium gray.....	36.8	334
27.	Ground glass.....	50.5	305
28.	Clear glass ("American").....	90.2	313

PLATE XIII.



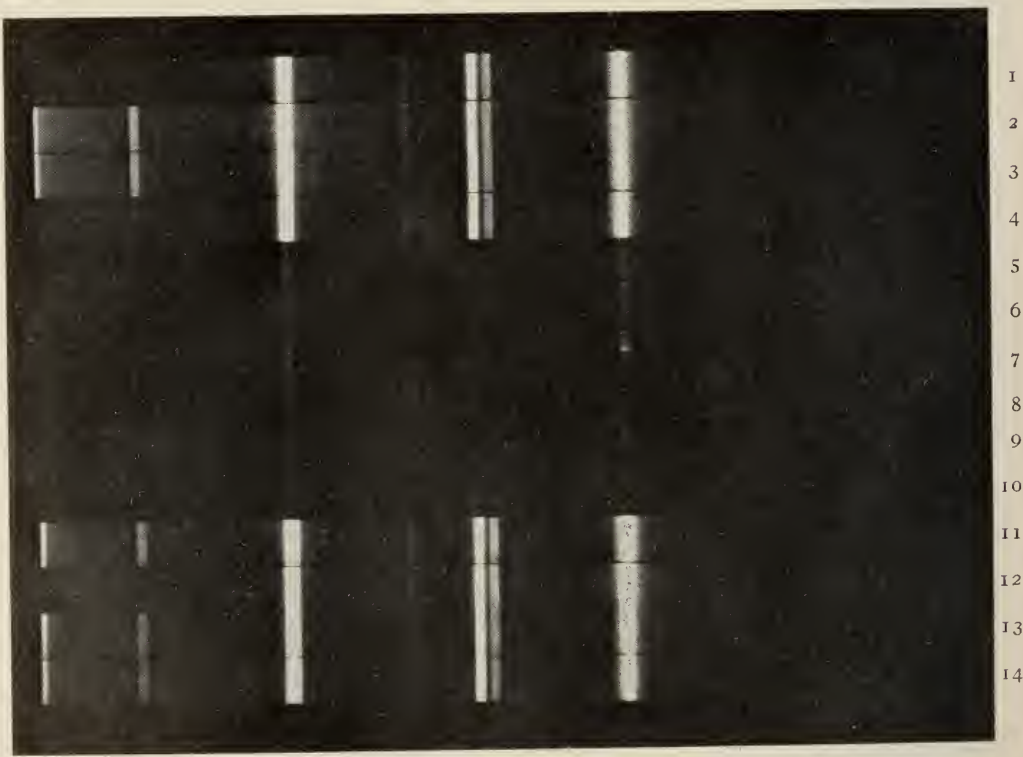
1.	Quartz.....	30 seconds.
2.	"American" glass.....	5 seconds.
3.	"American" glass.....	10 seconds.
4.	"American" glass.....	20 seconds.
5.	"American" glass.....	40 seconds.
6.	"American" glass.....	80 seconds.
7.	"American" glass.....	160 seconds.

PLATE XIV.



- | | |
|------------------------------|--------------|
| 1. 3.1 per cent. screen..... | 120 seconds. |
| 2. "American" glass..... | 120 seconds. |
| 3. 0.3 per cent. screen..... | 120 seconds. |
| 4. 0.3 per cent. screen..... | 60 seconds. |
| 5. Glass..... | 60 seconds. |
| 6. 3.1 per cent. screen..... | 60 seconds. |

PLATE XV.



- | | |
|-------------------------------|---------------|
| 1. 3 "American" glasses..... | 10.0 seconds. |
| 2. 80 per cent. screen..... | 10.2 seconds. |
| 3. 71 per cent. screen..... | 10.0 seconds. |
| 4. 3 "American" glasses..... | 10.0 seconds. |
| 5. 80 per cent. screen..... | 5.0 seconds. |
| 6. 3 "American" glasses..... | 5.0 seconds. |
| 7. 71 per cent. screen..... | 5.0 seconds. |
| 8. 60 per cent. screen..... | 5.0 seconds. |
| 9. 3 "American" glasses..... | 5.0 seconds. |
| 10. 53 per cent. screen..... | 5.0 seconds. |
| 11. 71 per cent. screen..... | 60.0 seconds. |
| 12. 3 "American" glasses..... | 60.0 seconds. |
| 13. 60 per cent. screen..... | 60.0 seconds. |
| 14. 53 per cent. screen..... | 60.0 seconds. |

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OCCURRENCE OF ALDEHYDES IN GARDEN AND FIELD SOILS.*

BY

OSWALD SCHREINER, Ph.D., and J. J. SKINNER, B.S.,

Fertility Investigations, Bureau of Soils, U. S. Department of Agriculture.

THE discovery of salicylic aldehyde¹ in a soil from the Mt. Vernon gardens, led to a study of the extent to which material of this type would be likely to be encountered in soil investigations. In extending this study to many soils it was not feasible to examine large quantities of each soil, so that it was not possible to clearly demonstrate the identity of the aldehyde obtained, but it was possible to so treat a sample of soil as to obtain the compounds of an aldehyde nature contained therein, separated from compounds having non-aldehyde properties. This aldehyde material was tested, so far as the quantity permitted, for such reactions as are given by salicylic aldehyde; namely, coloration with ferric chloride, and the general aldehyde reactions with fuchsine reagent. In all cases the aldehyde was subjected to the physiological test as to its effect on plant growth, using wheat seedlings in the well-known manner. It will be well to describe here the exact procedure employed in extracting the aldehyde material from the soil and the manner of testing the same.

Twelve to sixteen pounds of soil were used in the examination for aldehydes. The soil was extracted with eight litres of a 3 per cent. solution of sodium hydroxide. The solution was stirred for six to eight hours, and, after settling, the liquid poured off. The alkaline extract was acidified with sulphuric acid and filtered from the so-called humus precipitate. The acid filtrate was shaken out with several portions of ether, the ether extracts combined and shaken with a concentrated aqueous solution of sodium bisulphite, which will remove aldehydes from the ether solution if present, by forming a water-soluble combination with the sodium bisulphite. The bisulphite solution was separated from the ether, strongly acidified with sulphuric acid and air blown

* Communicated by Dr. Schreiner.

¹ Shorey, E. C., "Some Organic Soil Constituents," Bul. 88, p. 19, Bureau of Soils, U. S. Dept. Agric. (1913).

through to remove the sulphur dioxide liberated. This acidified solution, in which the aldehyde is now liberated from its combination with the bisulphite, was then shaken with several portions of fresh ether, the ether extracts combined, and the ether removed by evaporation. There was obtained a small quantity of material, often resinous or oily in appearance.

This material was further purified by again taking up in water, extracting with ether, and the ether solution, after filtering, allowed to evaporate. Sometimes this operation was repeated. The purified residue contains the aldehyde material, if present.

This aldehyde material was treated with a small quantity of water. The aqueous solution is frequently colored, and on evaporation a yellow oil is often noticeable, as would be the case if salicylic aldehyde were present. The odor of the latter is also sometimes observed, although in other cases other odors are perceptible, suggesting other aldehydes.

The fuchsine reagent was added to a portion of the solution, and to another portion a small amount of ferric chloride was added. Salicylic aldehyde, as mentioned, gives a violet color with ferric chloride and a pink color with the fuchsine reagent. Where both these reactions were observed the soil was considered as containing aldehydes. While the nature of the material is not thereby definitely shown to be salicylic aldehyde, yet the manner of isolation with ether, extractions therefrom with sodium bisulphite, together with the reaction shown with the fuchsine reagent, show the material to be an aldehyde, and the physical character of fluidity and the reaction with ferric chloride make it quite probable that in most of these cases salicylic aldehyde was under consideration. The amount obtained did not permit of further identification than is here given, especially as the main object was to determine the physiological property of the extracted material.

The main portion of the material, remaining after making the above tests, was dissolved or mixed with 250 c.c. of pure distilled water and the resulting liquid used as a culture for wheat seedlings so as to test the physiological effect of the extracted material from the soil.

In order to study the presence of this aldehyde in soils a number of samples were tested. Included in this test were a

number of soils sent to this Bureau from time to time by interested gardeners and greenhouse growers. The soils submitted were garden and greenhouse soils, on which the owners had had trouble in producing vegetables or flowers. Often the soils had grown good crops, were intensively cultivated and heavily manured, and later failed. In this respect the conditions were similar to those on the Mt. Vernon soil, in which the salicylic aldehyde was first discovered. This soil had been used for growing flowers and garden plants for a long period of years, had been intensively cultivated and heavily manured for a long time, had failed to show further response to manure, had been declining in productivity, and had been shown to contain salicylic aldehyde in the investigation reported. It seemed, therefore, interesting to include soils which in some degree had had a similar history.

In addition to this adventitious examination of soil samples a similar survey was made with soils collected in the open field by the fieldmen of this Bureau under instructions furnished them. Accordingly samples of field soils were collected from various parts of the United States. A productive sample and an unproductive sample of the same soil type, either from the same field or at least in the same vicinity, were sent in for the investigation. The history of the soils as to crops grown, fertilization, drainage, etc., was secured so far as available.

The results of this examination for the occurrence of aldehyde compounds in soils include good and poor samples from many parts of the United States, comprising acid, neutral and alkaline soils, soils of different cropping, different texture, origin, drainage conditions, climatic conditions, etc. The results of the examination of these soils will now be given.

A total of 74 soils are described in the two following tables. Of these, 14 are garden and greenhouse soils which had failed to grow good crops, and 60 are field soils under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. In this connection attention should again be called to the fact that the field samples were collected in pairs, one good and the other poor, of the same soil type and from the same field or locality.

These soils were all subjected to the method described for

obtaining aldehyde compounds from soils and the material thus obtained tested with the reagents mentioned. Five of the garden soils and twelve of the field soils gave an appreciable amount of aldehyde compounds when thus extracted, and this material gave positive reactions with the fuchsine reagent and with the ferric chloride. These soils are briefly described in Table I, together with the results obtained when the material was tested in the manner described with seedling wheat.

In Table II are given the remaining soils, which gave none or only an insignificant amount of extractive material when subjected to the method of obtaining aldehyde material from soils, nor did this extract give the reactions with the above reagents. We must conclude, therefore, that the aldehyde material—salicylic aldehyde or other aldehydes—is either absent or present in much smaller quantities in the soils of Table II than in the soils given in Table I.

From Table I it will be seen that the soil aldehyde is in every case harmful to growth, as shown in the next to the last column, and behaves in this respect like the Mt. Vernon soil (No. 1), which has been already more fully described and in which salicylic aldehyde of poisonous properties was demonstrated. The effect of the soil aldehyde was tested on wheat by growing the plants in water cultures. An experiment was made with the aldehyde in pure distilled water. The wheat was grown in water in culture jars holding 250 c.c. One jar contained pure distilled water, and the second contained the water in which was dissolved the aldehyde separated from the soil. The plants grew for two weeks. The aldehyde was quite harmful, reducing growth about 37 per cent. Another experiment was made, using a good nutrient solution with and without the substance. The aldehyde from the soil was extremely harmful, even in the good nutrient solution; the green weight of the plants was reduced 40 per cent. These experiments with the salicylic aldehyde extracted from the soil are shown in Fig. 1. The plants show the harmful effect of the substance on growth. It will be seen that both tops and roots in nutrient solution and in distilled water are badly affected by the presence of the salicylic aldehyde.

In Fig. 2 is shown the effect of this material from soil No. 2. This had been used for gardening and trucking for the

TABLE I.
Soils in Which Aldehydes were Demonstrated.

No.	Soil	Field record	Location	Crop on soil when sample was taken	Reaction of soil	Effect of extracted aldehyde material on growth of wheat	Notes
1	Garden soil, loam.....	...	Mt. Vernon, Va.....	Flowers.....	Acid.....	Very harmful.....	Rich loam, well manured for over a century.
2	Garden soil, silt loam.....	...	Mechanicsburg, Pa...	Vegetables.....	Very acid.....	Very harmful.....	Poultrymanure and commercial fertilizers for 70 years.
3	Garden soil, red loam.....	...	Orange, N. J.....	Vegetables.....	Acid.....	Slightly harmful.....	Rich loam; declining. Heavy manuring ineffective.
4	Truck soil, red loam.....	...	Chester Co., Pa.....	Truck crops....	Alkaline.....	Very harmful.....	Commercial fertilizers and rotation. Trucked for 20 years. Crops now failing. Soil contains excess of salts (15 per cent). Subsoil also contains aldehyde material.
5	Greenhouse soil, loam.....	...	Arlington, Va.....	Flowers.....	Neutral.....	Very harmful.....	Heavily manured.
6	Memphis silt loam.....	Poor...	Lafayette Co., Miss..	Grass.....	Acid.....	Very harmful.....	Pasture 20 years.
7	Aurora silt loam.....	Good..	Miller Co., Mo.....	Corn.....	Slightly acid....	Harmful.....	No fertilizer.
8	Norfolk very fine sandy loam....	Good..	Pender Co., N. C.....	Cotton.....	Acid.....	Harmful.....	Manure occasionally. No fertilizers.
9	Norfolk very fine sandy loam....	Poor...	Pender Co., N. C.....	Cotton.....	Acid.....	Very harmful.....	Well manured. Occasionally fertilized.
10	Portsmouth silt loam.....	Poor...	Perquimans Co., N. C.	Corn.....	Slightly acid....	Harmful.....	No manure, 200 pounds commercial fertilizer.
11	Miami stony loam.....	Poor...	Oneida Co., N. Y.....	Meadow.....	Acid.....	Harmful.....	No manure, 200 pounds fertilizer.
12	Ontario loam.....	Poor...	Oneida Co., N. Y.....	Corn.....	Neutral.....	Harmful.....	Not fertilized.
13	Muskogee silt loam.....	Poor...	Muskogee Co., Okla..	Cotton.....	Acid.....	Harmful.....	Stable manure.
14	Norfolk fine sandy loam.....	Poor...	Georgetown, S. C.....	Corn.....	Acid.....	Harmful.....	No manure. No fertilizer.
15	Salt Lake clay.....	Poor...	Cache Co., Utah.....	Wheat.....	Alkaline.....	Harmful.....	Drainage poor.
16	Dekalb silty clay loam.....	Good..	Preston Co., W. Va....	Grass.....	Slightly acid....	Harmful.....	Manured.
17	Dekalb silty clay loam.....	Poor...	Preston Co., W. Va....	Fallow.....	Slightly acid....	Harmful.....	No manure; low-grade fertilizer used.

last ten years, and had been manured each year with poultry manure and commercial fertilizers. The soil in the last two years produced poor vegetables and truck crops, and corn failed entirely. The soil is grayish yellow in color, is quite acid, and is low in organic matter. The separated aldehyde extract was harmful to growth of wheat seedlings, causing a decrease of 33 per cent.

FIG. 1.



Effect of salicylic aldehyde extracted from Mt. Vernon garden soil on wheat seedlings. (No. 1, nutrient solution; No. 2, nutrient solution plus salicylic aldehyde; No. 3, distilled water; No. 4, distilled water plus salicylic aldehyde.)

In Fig. 3 is shown the effect of the aldehyde extract from a soil (No. 4, from Chester County, Pennsylvania) showing an alkaline reaction. This soil had been growing vegetables and truck crops for 20 years with frequent use of commercial fertilizers. Corn, cabbage, and cantaloupes had failed in certain sections of the field for the last two years, whereas formerly the soil grew excellent truck crops of all kinds. The soil and sub-

soil were quite alkaline to litmus paper, and both showed the presence of considerable aldehyde material. This reduced growth of the test plants by 26 per cent., both tops and roots being severely injured.

The heavily manured greenhouse soil (No. 5, Table I) is particularly interesting in that considerable aldehyde was found therein, whereas neither the raw soil (No. 8, Table II) nor similarly treated soil which had been used and then weathered

FIG. 2.

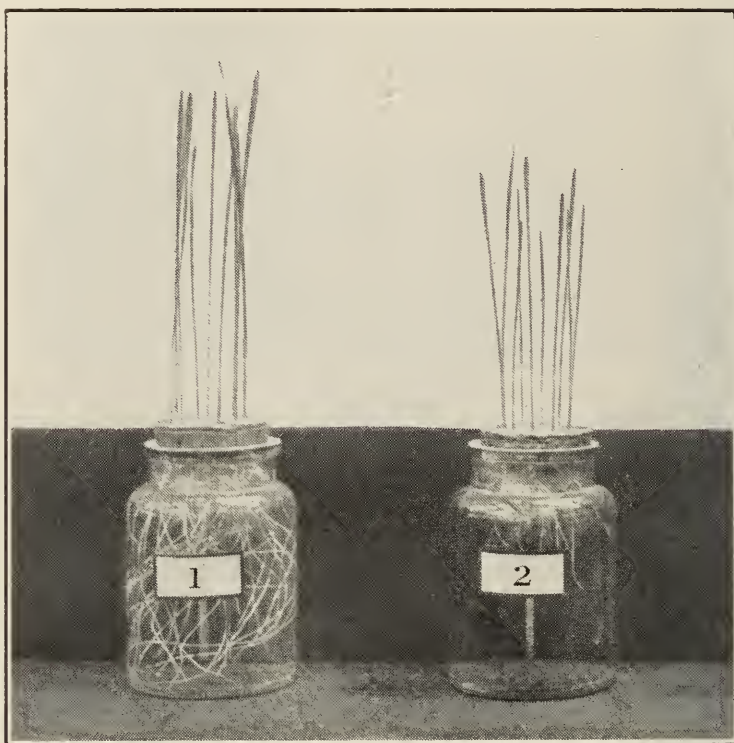


Effect of aldehyde extracted from garden soil (No. 2) from Mechanicsburg, Pennsylvania, on growth. (No. 1, distilled water; No. 2, distilled water plus aldehyde.)

for some time (No. 7, Table II) contained the harmful aldehyde material. This examination was made because the soil in question had been used on benches for floriculture and did not give good results. Soil No. 5, Table I, was a composite taken from two benches in the greenhouse where carnations and roses did not thrive. This contained aldehyde, which when tested with wheat seedlings gave reductions in growth of 35 per cent. Soil No. 7, Table II, had been previously used for greenhouse purposes and had been made in the same way by manuring heavily

the raw soil, but without experiencing any difficulty. Since then it had been in a pile outside for several months. At the time of testing no aldehyde could be found, nor was the residue obtained harmful to the seedling wheat. Soil No. 8, Table II, was some of the raw soil as it was hauled from the field previous to the incorporation of manure in preparation for greenhouse use. No aldehyde could be detected in this soil, nor did such residue as was obtained in this procedure show any harmful effect.

FIG. 3.



Effect of aldehyde extracted from a poor garden soil (No. 4) on wheat seedlings. (No. 1, distilled water; No. 2, distilled water plus aldehyde from garden soil.)

Soil No. 11, the poor sample of Miami stony loam, contained aldehyde, and the depressed growth obtained is shown in Fig. 4, together with the effect of the identically extracted good field sample. The latter showed no aldehyde reactions, but, as seen from the photograph, it was nevertheless, somewhat harmful, a fact which is recorded in Table II, under No. 41.

Soil No. 12, the Ontario loam, poor, from Oneida County, New York, together with its good companion sample, recorded

as soil No. 42, in Table II, presents an interesting story. In 1907 both fields were poor, unproductive soils. Both fields were manured heavily every year. One field responded to this treatment, the other did not.

The field represented by soil No. 42, Table II, grew corn in 1907, and produced a poor crop. In 1908 the field was manured and planted to oats, giving a good yield. It was manured every year after this. In 1909 and 1910 hay was grown with good

FIG. 4.



Effect of substance extracted from poor and good Miami stony loam on wheat plants. (No. 1, distilled water; No. 2, distilled water plus material from poor soil containing aldehydes; No. 3, distilled water plus material from good soil showing no aldehyde reactions.)

results, the largest crop being in 1910. In 1911 an excellent crop of corn was grown, and in 1912 oats were again grown with good yields.

The field represented by soil No. 12, Table I, was in meadow in 1907, and gave poor yields. In 1908 the field was manured and planted to corn, which failed entirely. It was manured every year after this without good results. In 1909 oats were planted, but made very little growth. In 1910 and 1911 grass was sown

TABLE II.
Soils in Which no Aldehydes could be Demonstrated.

No.	Soil	Field record	Location	Crop on soil when sample was taken	Reaction of soil	Effect of extracted material on growth of wheat	Notes
1	Garden soil, loam.	....	Washington, D. C.	Flowers.	Acid.	No effect.	Heavily manured.
2	Garden soil, loam.	....	Pittsburgh, Pa.	Flowers.	Acid.	No effect.	Manured. Responds to lime.
3	Garden soil, gray sandy loam.	....	Philadelphia, Pa.	Garden crops.	Acid.	Harmful.	Well manured.
4	Garden soil, loam.	....	Phoenixville, Pa.	Garden crops.	Alkaline.	No effect.	Salt content high.
5	Garden soil, gray loam.	....	Philadelphia, Pa.	Garden crops.	Alkaline.	No effect.	Drainage poor.
6	Garden soil, waxy black.	....	Greene Co., Ind.	Garden crops.	Acid.	No effect.	Responds to lime and potash fertilizers.
7	Greenhouse soil, loam.	....	Arlington, Va.	Flowers.	Neutral.	No effect.	Soil had weathered for months since it had been used in floriculture.
8	Greenhouse soil, raw soil.	....	Arlington, Va.	....	Acid.	No effect.	Poor raw soil used as basis for greenhouse soil No. 7, this table, and No. 5, table I. Calcareous soil.
9	Dark gray loam.	....	Sanford, Florida	Citrus trees.	Alkaline.	No effect.	
10	Tifton sandy loam.	Good.	Covington Co., Ala.	Corn.	Slightly acid.	Harmful.	
11	Tifton sandy loam.	Poor.	Covington Co., Ala.	Corn.	Slightly acid.	Harmful.	
12	Huntington fine sandy loam.	Good.	Pope Co., Ark.	Corn.	Slightly acid.	Slightly beneficial.	
13	Huntington fine sandy loam.	Poor.	Pope Co., Ark.	Corn.	Slightly acid.	Slightly beneficial.	
14	Decatur clay loam.	Good.	Chattooga Co., Ga.	Cotton.	Acid.	Not tested.	
15	Decatur clay loam.	Poor.	Chattooga Co., Ga.	Cotton.	Acid.	Not tested.	
16	Neosho silt loam.	Good.	Cherokee Co., Kan.	Wheat.	Slightly acid.	Beneficial.	
17	Neosho silt loam.	Poor.	Cherokee Co., Kan.	Corn.	Slightly acid.	Beneficial.	
18	Colby silt loam.	Good.	Jewell Co., Kan.	Corn.	Neutral.	Beneficial.	
19	Colby silt loam.	Poor.	Jewell Co., Kan.	Wheat.	Neutral.	Beneficial.	
20	Osage loam.	Good.	Greenwood Co., Kan.	Grass.	Alkaline.	Beneficial.	
21	Osage loam.	Poor.	Greenwood Co., Kan.	Corn.	Alkaline.	Beneficial.	
22	Dekalb silt loam.	Good.	Christian Co., Ky.	Clover.	Neutral.	No effect.	
23	Dekalb silt loam.	Poor.	Christian Co., Ky.	Tobacco.	Neutral.	Slightly harmful.	
24	Miami loam.	Good.	Genesee Co., Mich.	Grass.	Slightly acid.	Harmful.	
25	Miami loam.	Poor.	Genesee Co., Mich.	Wheat.	Slightly acid.	Harmful.	
26	Carrington silt loam.	Good.	Goodhue Co., Minn.	Barley.	Slightly acid.	Beneficial.	
27	Carrington silt loam.	Poor.	Goodhue Co., Minn.	Grass.	Slightly acid.	Beneficial.	
28	Memphis silt loam.	Good.	Lafayette Co., Miss.	Corn.	Neutral.	No effect.	

29	Summit silt loam.	Good.	Cass Co., Mo.	Oats.	Not tested.	No effect.
30	Summit silt loam.	Poor.	Cass Co., Mo.	Wheat.	Not tested.	No effect.
31	Aurora silt loam.	Poor.	Miller Co., Mo.	Millet.	Slightly acid.	No effect.
32	Freehold loam.	Good.	Monmouth Co., N. J.	Grass.	Slightly acid.	Beneficial.
33	Freehold loam.	Poor.	Monmouth Co., N. J.	Corn.	Slightly acid.	Slightly harmful.
34	Dutchess silt loam.	Good.	Orange Co., N. Y.	Millet.	Neutral.	Slightly harmful.
35	Dutchess silt loam.	Poor.	Orange Co., N. Y.	Grass.	Neutral.	Harmful.
36	Chandler loam.	Good.	Ashe Co., N. C.	Corn.	Neutral.	No test.
37	Chandler loam.	Poor.	Ashe Co., N. C.	Corn.	Neutral.	No test.
38	Toxaway fine sand.	Good.	Ashe Co., N. C.	Grass.	Slightly acid.	Harmful.
39	Toxaway fine sand.	Poor.	Ashe Co., N. C.	Grass.	Slightly acid.	Harmful.
40	Portsmouth silt loam.	Good.	Perquimans Co., N. C.	Cotton.	Slightly acid.	Harmful.
41	Miami stony loam.	Good.	Oneida Co., N. Y.	Corn.	Acid.	Slightly harmful.
42	Ontario loam.	Good.	Oneida Co., N. Y.	Oats.	Neutral.	Slightly harmful.
43	Muskogee silt loam.	Good.	Muskogee Co., Okla.	Peanuts.	Acid.	Beneficial.
44	Berks shale loam.	Good.	Lehigh Co., Pa.	Grass.	Slightly acid.	No effect.
45	Berks shale loam.	Poor.	Lehigh Co., Pa.	Grass.	Slightly acid.	No effect.
46	Norfolk fine sandy loam.	Good.	Georgetown Co., S. C.	Wheat.	Slightly acid.	No effect.
47	Clarksville silt loam.	Good.	Robertson Co., Tenn.	Wheat.	Acid.	No effect.
48	Clarksville silt loam.	Poor.	Robertson Co., Tenn.	Clover.	Acid.	No effect.
49	Jordan loam.	Good.	Cache Co., Utah.	Oats.	Alkaline.	Beneficial.
50	Jordan loam.	Poor.	Cache Co., Utah.	Oats.	Alkaline.	Beneficial.
51	Salt Lake clay.	Good.	Cache Co., Utah.	Wheat.	Alkaline.	Slightly harmful.
52	Carrington silt loam.	Good.	Dane Co., Wis.	Tobacco.	Neutral.	Harmful.
53	Carrington silt loam.	Poor.	Dane Co., Wis.	Oats.	Acid.	Harmful.
54	Sioux fine sandy loam.	Good.	Buffalo Co., Wis.	Corn.	Slightly acid.	No effect.
55	Sioux fine sandy loam.	Poor.	Buffalo Co., Wis.	Rye.	Slightly acid.	No effect.
56	Miami silt loam.	Good.	Jefferson Co., Wis.	Corn.	Neutral.	Harmful.
57	Miami silt loam.	Poor.	Jefferson Co., Wis.	Alfalfa.	Neutral.	Harmful.

and gave poor results. In 1912 the soil was heavily manured and again planted to corn. The yield of stover was very poor and no grain was formed.

The laboratory examination of the two soils showed them to be neutral in reaction. The good soil gave no reactions for aldehyde when extracted for this purpose, but the extractive material was slightly harmful. The poor soil, however, gave considerable amounts of aldehyde material, and this was distinctly harmful to the wheat seedlings, reducing growth 28 per cent.

Soil No. 15, the Salt Lake clay from Cache County, Utah, is from a poor spot in an otherwise good field. The remainder of the field is represented by soil No. 51, Table II, and was collected about 35 feet away from the poor spot. The color of the soil in the poor spot is light gray, while the good soil is gray with a pink tint. This spot is generally bare and seldom produces a crop, while the remainder of the field is very productive, yielding from 20 to 30 bushels of wheat per acre. The drainage in the spot is poorer than the remainder of the field. The sub-soil of both good and poor soil is a light calcareous clay. Both soils are alkaline in reaction and both showed the same content of water-soluble salts (.03 per cent.). The good sample contained no aldehydes, and such residue as was obtained proved only slightly harmful to wheat seedlings, whereas the poor sample contained considerable aldehydes, which proved very harmful to wheat seedlings in the cultural tests, reducing growth 30 per cent.

Returning now to a discussion of Table I, as a whole, it has been shown that the aldehyde extract is uniformly harmful to the test plants. This becomes apparent from the next to the last column of the table.

In the third column is given the field record of the soils as to their productivity as designated by the collector. The garden soils, as already mentioned, were all soils with which trouble of one kind or another had been experienced. In general this column shows that the soils containing the aldehyde were also poor soils in garden and field, with some few exceptions. In this column is found one notable exception, in the Aurora silt loam, good (No. 7), from Miller County, Missouri. This soil contained aldehyde, whereas the corresponding poor sample

(No. 31, in Table II) from another farm gave no indication of the presence of aldehyde. This observation was confirmed by procuring a new sample 6 months later. The other exceptions are in the Norfolk very fine sandy loam (No. 8) and in the Dekalb silty clay loam (No. 16), in which aldehyde was found, but it will be noticed that in both these cases the poor soil contained the aldehyde also (Nos. 9 and 17). It would appear, therefore, that both good and poor soil samples contained some aldehyde. It might be further pointed out that in both cases the greater productivity of the sample designated as good is doubtless due to the direct fertilizing value of the applied manure, the less productive samples having no manure applied. That manure is not antagonistic to aldehyde is indicated by its presence in the exceedingly well manured garden soils, in the same table (see notes in last column), as well as by some of the field results already given.

Some of the soils given in Table II and showing no aldehydes have been discussed in connection with the preceding table. The remainder require no further discussion here, inasmuch as no aldehyde was found in either the good or poor sample.

From these two tables it is at once apparent that only a relatively small number of the poor soils showed the presence of aldehyde, which means that the poorness of many of the soils in Table II must be attributed to other causes, since soil infertility may be due to a great many factors other than the presence of toxic compounds, and especially any particular toxic compound.

The material extracted in the aldehyde method was in all cases extremely small, gave no aldehyde reactions, but in some cases it proved, nevertheless, harmful. What the nature of the harmful substance in these cases was it is impossible to state. If aldehyde was present, it was at least so small in amount that it escaped chemical detection, nor does the method wholly exclude the occurrence at this place of traces of other compounds. In the majority of cases the material was not harmful, occasionally even showing a slightly good or stimulating effect.

A total of 74 soils is described in the foregoing tables. Of these, 14 were garden and greenhouse soils which had failed to grow crops, and 60 were field soils under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive.

These soils were all examined for aldehydes. Of the 14 garden soils, 5 contained aldehydes, and of the 60 field soils, 12 contained aldehydes.

(1) *In Soils from Widely Different Sections.*—The soils examined were from various parts of the United States; soils from 20 States make up the list. They vary from very unproductive soils to extremely fertile soils.

Aldehydes were found in soils from 9 States as widely separated as New York and Mississippi or Oklahoma. Its presence is, therefore, not confined to any locality.

(2) *In Soils of Different Texture.*—The soils in which the aldehyde occurred are not soils of any specific type or texture. The above list of soils containing the aldehyde comprises clays, clay loams, silt loams, silty clay loams, loams, stony loams, fine sandy loams, and very fine sandy loams. There is, therefore, no apparent relation with soil type or texture.

(3) *In Unproductive Soils.*—The unproductive soils examined can be divided into two classes: (1) Garden soils, comprising soils which have been highly fertilized and manured, heavily cropped and intensively cultivated, and later failed to produce good crops. This class includes several greenhouse soils. (2) Field soils, growing general farm crops with ordinary farm methods of cultivation.

Fourteen poor garden soils were examined, five of which contained aldehydes. All of these soils were very unproductive and failed entirely or grew very poor garden crops. Nine of the 30 unproductive field soils examined contained aldehydes.

(4) *In Productive Soils.*—Of the 30 productive soils examined, 3 contained aldehydes. These were the Aurora silt loam, from Miller County, Missouri; Norfolk very fine sandy loam, from Pender County, North Carolina; and Dekalb silt loam, from Preston County, West Virginia.

(5) *In Acid, Alkaline, and Neutral Soils.*—It is interesting to note that some of the soils which contained aldehydes were acid, some neutral, and others alkaline. Three of the garden soils (Nos. 1, 2, and 3) were acid, one (No. 4) was alkaline, and one (No. 5) was neutral. Of the field soils which contained the aldehyde, ten were acid, one alkaline, and one neutral.

(6) *In Soils Growing Different Crops.*—Four of the soils

which were found to contain aldehydes were garden soils and had been used for growing garden crops continuously for several years. One was a greenhouse soil and had grown carnations and roses.

Twelve of the soils in which aldehyde was found were used for the growth of general field crops. A rotation of several crops was practised on most of these soils. At the time the samples were collected three were in grass, four were growing corn, three were growing cotton, one was in wheat, and one was fallow. These observations, together with the fact that no aldehydes were found on other soils growing the same crop, would seem to indicate that no close relation exists between the crop being grown and the presence of aldehyde.

Rusting of Iron in Water. W. A. BRADBURY. (*Chem. News*, cviii, 307.)—Many years ago Crace Calvert concluded that the rusting of iron in water was occasioned by dissolved carbonic acid and oxygen, the former being the predisposing cause, since no action occurred in its absence. These conclusions have since been widely supported. Experiments conducted by the author show that rusting takes place very rapidly in tap-water, while in well boiled tap-water no rusting should occur. During rusting atmospheric oxygen is absorbed. The solution of iron by carbonic acid should result in the production of hydrogen, thus $\text{Fe} + 2\text{H}_2\text{CO}_3 = \text{FeH}_2(\text{CO}_3)_2 + \text{H}_2$, but in experiments with tap-water no gas could be collected after over a week. Water saturated with CO_2 did evolve considerable quantities of gas. These experiments confirm the view that rusting is due to the combined action of oxygen and carbonic acid, and show that the oxygen is utilized in two ways: (*a*) in the oxidation of the nascent hydrogen liberated, and (*b*) in the oxidation of the iron bicarbonate to rust. Further tests showed that magnesium chloride solution does not act on iron in the absence of carbonic acid, although it has been stated that such solutions do react with iron, even in the cold, according to the equation— $\text{Fe} + \text{MgCl}_2 + 2\text{H}_2\text{O} = \text{Mg}(\text{OH})_2 + \text{FeCl}_2 + \text{H}_2$.

Resistanceless Conductors, Hence Permanent Magnets?

ANON. (*Sci. Amer.*, cx, No. 25, 497.)—For many years the laboratory of Prof. Kammerlingh Onnes at Leyden has been the centre from which some of the most important advances in low temperature research have been announced. It will be remembered that the Dutch physicist was the first to liquefy helium, the most refractory of all known gases, and that in the course of the experiments the lowest temperature on record, within a degree or so of absolute zero, was obtained. Lately attention has been centred on the remarkable influence of temperature on the electrical resistance of metals. This resistance becomes practically zero before the absolute zero of temperature is reached. Recent newspaper accounts state in somewhat vague terms that remarkable new developments have followed in the train of this work on the conduction of electricity at low temperatures. The question arises, What happens to an electric current once started in a conductor of zero resistance? Its energy is not dissipated as heat, since the ohmic effect is non-existent. Does the current continue to flow indefinitely? If so, a closed loop carrying a current would function as a permanent electromagnet. It is said that something of this kind has been observed.

Rolling of Zinc. ANON. (*The Metal Ind.*, xii, No. 6, 247.)—

Experiments have been made in Belgium to ascertain the effects of foreign metals on the rolling of zinc. Ingots weighing 40 pounds were prepared by casting zinc alloys of various metals, with spelter containing lead 1.05 to 1.25 per cent., cadmium 0.076 to 0.11, and iron 0.03 to 0.039 per cent. Cadmium is harmful above 0.25 per cent., while with 0.5 per cent., rolling is impossible. Arsenic, 0.02 per cent. markedly increases the hardness, and with 0.03 per cent. the metal is too brittle for practical purposes. Antimony is less objectionable than arsenic, as 0.07 per cent. does not increase the hardness; but 0.02 per cent. is enough to produce a striated surface on the rolled sheet, which makes it unsalable. Tin is objectionable when over 0.01, and prohibitive at 0.03 per cent. Copper does not harden until it reaches 0.08, and with 0.19 per cent. the zinc is unworkable. A permissible maximum of iron is 0.12 per cent., but this is easily reduced in refining. Though 1 to 1.25 per cent. of lead does not interfere with the rolling, a slight increase not only seriously affects the malleability, but the excess of lead remains unalloyed and forms patches on the sheet. The presence of two or more impurities together results in a combination of the injurious effects of each.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

COMBUSTION CALORIMETRY AND THE HEATS OF COMBUSTION OF CANE SUGAR, BENZOIC ACID, AND NAPHTHALENE.¹

Hobert C. Dickinson.

THE uniform standardization of combustion calorimeters of the Berthelot bomb type can best be accomplished by the combustion of substances having a known heat of combustion.

Part II of this paper deals with a series of determinations of the heats of combustion of three of these substances,—sugar, benzoic acid, and naphthalene,—while Part I deals with a study of the general problem of the bomb calorimeter.

A critical study of the stirred water calorimeter as used for bomb combustion shows that the sources of error are mainly of four kinds; viz., (1) temperature measurement, (2) evaporation, (3) lag effect (*i.e.*, failure of some parts of the system to reach a steady condition with sufficient speed), and (4) uncertainties as to the boundaries of the calorimeter (*i.e.*, as to what portions should be included in its heat capacity). It is shown that most of the errors may be avoided by the use of resistance thermometers and by the proper construction of the calorimeter and its jacket.

The cooling corrections for a calorimeter, designed in accordance with the conclusions reached, can be made by a very simple procedure and with an accuracy corresponding to perhaps 1 part in 10,000 of the total amount of heat measured.

A method of electrical calibration was used, which enables the results of combustion observations to be expressed directly in calories almost independently of the electric units, or, if the heat capacity of the electric heating element used in the calibration is known, to be used to check serious errors in either the calorimetric system or the electrical calibrating system.

Observations have been made with two different calorimeters

* Communicated by the Bureau.

¹ Scientific Papers of the Bureau of Standards.

built especially for the purpose and each calibrated by the above method several times independently. Both calibrations and combustions cover a period of more than three years during which time hundreds of observations have been made with different electrical equipment, and samples of material obtained from different sources and purified at different times and in different ways.

Determinations of the heat of combustion of naphthalene gave 9622 ± 2 20° calories per gramme weighed in air, with a maximum deviation from the mean of about 5 in 10,000 for groups of observations upon the same samples and about the same maximum deviation of different groups of observations from the mean of all, regardless of the sample.

Determinations of the heat of combustion of benzoic acid gave 6329 ± 1 20° calories per gramme weighed in air, with a maximum deviation of about 1 in 1000 for the earlier experiments and 5 in 10,000 for the later ones. Observations taken on samples, some by no means pure, from different sources, show a maximum deviation of 15 in 10,000 and a mean deviation of 7 in 10,000.

Determinations of the heat of combustion of sucrose, fewer in number, gave 3949 ± 2 20° calories per gramme weighed in air. The later observations show a maximum deviation of a little less than 1 in 1000 and a mean deviation of about 3 in 10,000, though the earlier ones show a maximum deviation of 15 in 10,000.

It appears that, of the three materials included in this investigation, benzoic acid is the most desirable as a combustion standard, as indicated by the agreement between the results of different observers. Naphthalene has been found very reliable and convenient, although it requires care in handling since a gramme briquet will lose more than 1 milligramme per hour by sublimation. An accuracy of 3 parts in 10,000 is attainable.

Sucrose seems not to be so well adapted for use as a combustion standard as is benzoic acid because of its lower heat of combustion, its frequent failure to ignite, and the lower precision of the results obtained.

Various factors, viz., temperature measurement, stirring, thermal conduction, convection, boundaries of the calorimeter, cooling corrections and lag effects, affecting the accuracy of calo-

rimeters, are discussed and some of the principles involved in the design of an accurate calorimeter are pointed out.

An electrical method used in the calibration of bomb calorimeters is described and discussed.

The results of an extended series of determinations of the heats of combustion of sucrose, benzoic acid, and naphthalene are tabulated and discussed.

The paper also contains a partial bibliography of the subject.

[ABSTRACT]

THE TESTING OF POTENTIOMETERS.*

Frank Wenner and Ernest Weibel.¹

FOR precise measurements with a potentiometer the errors in the adjustment of the resistance sections or coils in the apparatus must be known. These errors can be determined by measurements of the resistances of the various sections, but, without some systematic method of applying corrections, are not easily allowed for in the use of the potentiometer.

We have found that it is convenient to express the relation between the known electromotive force, the unknown electromotive force, the readings and the corrections by the formula

$$E = f [(e_1 + a_1) + (e_2 + a_2) + \text{etc.}] (1 + b + c + d) \dots (1)$$

where

E is the value of the unknown electromotive force,

f is the range readings,

e_1 is the reading of the highest dial,

e_2 is the reading of the next highest dial, etc.,

$c = \frac{S - s}{s}$ where S is the value of the known electromotive force and s is the reading of the known electromotive force dial or dials, and

b , d , a_1 and a_2 , etc., are small corrections due to errors in the adjustment of the various resistance sections.

The correction a_1 depends only on the reading e_1 , a_2 depends only on e_2 , etc., b depends only upon the reading s , and d depends only upon f . A table can therefore be constructed for each dial

* Presented at the Washington, 1914, meeting of the American Physical Society.

¹ Scientific Papers of the Bureau of Standards.

giving the corrections corresponding to each of its possible readings.

Let R_e be the resistance in the potentiometer between the E -terminals and R_s that between the S -terminals. Then if the total current is independent of the settings of the various switches or plugs,

$$E = S R_e / R_s = f [(c_1 + a_1) + (c_2 + a_2) + \text{etc.}] (1 + b + c + d) \dots (2)$$

Thus if R_e/R_s is determined for the various readings of f , of c and of s the corrections b , d , a_1 , a_2 , etc., can be determined.

In the paper various methods which have been used in the Bureau of Standards for measuring, or determining, the relative values of the resistance sections of different types of potentiometers are described. Also a procedure is given by which, for certain types of potentiometers, the corrections b , d , a_1 , a_2 , etc., may be obtained from the relative values of the resistance sections.

In order to reduce the time required for making the measurements and to obtain the data in such form that the corrections can be more easily calculated, a special piece of apparatus was constructed and has been in use during the past two years. This apparatus, which we shall call a ratio set, has been found to furnish a rapid and direct means for calibrating all types of potentiometers which have so far been submitted to the Bureau of Standards for test. It is equivalent to 211 110 resistance sections of .01 ohm each, connected in series and so arranged that a branch connection (either to battery or galvanometer) can be made between any two adjacent sections; or it is equivalent to a slide wire on which contact can be made at 211 110 points. The apparatus is made of 100 resistance sections, 20 of each of the following denominations; 100 ohm, 10 ohm, .1 ohm, and .01 ohm. Five dial switches serve to shift resistance sections from one side to the other of the branch connection, or to cut out sections on one side and insert corresponding sections into the other side.

In use the ratio set is connected in parallel with the potentiometer to be tested in such a way as to form two arms of a bridge, while the potentiometer forms the other two arms. This arrangement constitutes a Matthiessen and Hockin bridge. The ratio set is adjusted so that a balance of the bridge is obtained for each setting of the dials of the potentiometer for which corrections are

desired. The corresponding readings of the ratio set (when connected for known errors in its resistance sections) give data from which the corrections b , d , a_1 , a_2 , etc., of equation (1) may be calculated.

Certain adjustments are made (which cannot be explained in a short abstract), such that the corrections are obtained almost directly from readings of the potentiometer and ratio set.

The paper is to be published in the Bulletin of the Bureau of Standards and reprinted as Scientific Paper No. 223. Reprints will be ready after about September 1, 1914, and may be obtained by request from the Director, Bureau of Standards, Washington, D. C.

[ABSTRACT]

**AN EXPERIMENTAL STUDY OF THE KOEPEL
PERMEAMETER.***

Charles W. Burrows.

THIS paper gives in detail the results of an experimental study of the possibilities and limitations of the Koepsel permeameter. Data are given to show the influence of the length, cross section, and material of the specimen tested. The different factors which may affect the accuracy of the readings are considered, and the following detailed conclusions drawn:

1. Readings on the two sides of the zero of the instrument may differ considerably, but the mean of the two values thus obtained shows satisfactory consistency on repetition.

2. Shearing curves for different grades of material show that the correction to be applied to the observed magnetizing force is not constant for a given induction, but depends upon the nature of the test specimen. This correction is usually subtractive for points below the knee of the induction curve and additive for points above the knee.

3. An increase in the cross section of the test specimen tends to increase the observed values of the magnetizing force for points below the knee of the induction curve, and to decrease the observed values for points above the knee.

4. The length of the specimen projecting beyond the yokes

* Scientific Papers of the Bureau of Standards.

produces no noticeable effect for points below the knee of the induction curve. For points above the knee the projecting ends increase the observed value of the magnetizing force.

5. If the bushings are not pushed all the way into their proper position, a higher apparent value of the magnetizing force is observed due to the increased length of the portion of the bar under test.

6. Hysteresis loops obtained by the Koepsel permeameter always show a low observed residual induction and a high observed coercive force.

7. A theoretical and experimental study of the distribution of the magnetic fluxes through different parts of the magnetic circuit shows that shearing curves of the form observed are to be expected.

Apparatus of this type, if used without correction, may yield data greatly in error. The results of the present study show that for small and moderate inductions the measured magnetizing force is usually in excess of its true value, sometimes by as much as 100 per cent. At high inductions the measured magnetizing force is usually too low by an error which may be as great as 25 per cent. However, with care, and the use of proper correction curves, the apparatus is capable of yielding quantitative normal induction data in which the error in the magnetizing force is not greater than 5 per cent.

Uncorrected hysteresis data for hard steel show values of the residual induction that are too small by an error which may be as much as 10 per cent., while the coercive forces are too large by an error which may be as much as 40 per cent.

The chief value of such an instrument is for comparative work in which it is desired to determine the degree of uniformity of material or the relative values of similar materials.

SAFETY RULES TO BE OBSERVED IN THE OPERATION AND MAINTENANCE OF ELECTRICAL SUPPLY UTILITIES AND IN HANDLING ELECTRICAL EQUIPMENT.*

THE study of life and property hazards incident to the generation, distribution, and use of electrical energy includes the con-

* Abstract of Circular No. 49.

sideration of both construction methods and operating practice. Analysis of the available data on electrical accidents demonstrates their preventability in very large proportion by use of definite operating precautions. This is especially true with those accidents occurring to workmen engaged in electrical work.

Rules for construction, installation, and maintenance of electrical equipment to safeguard employes and the public are now under preparation by the Bureau of Standards. The rules for safety in the operation and handling of electrical lines and equipment, to be published shortly in their first edition under the above title, proceed from a painstaking study by the engineers of the Bureau of existing rules and practices. These are found to vary widely and to offer a very unsatisfactory basis for the formulation of mandatory codes by any State commission, unless a very extended study is made and the combined experience of many companies and workmen utilized. Many existing sets of rules have been developed from insufficient data and experience, while the vast majority of companies have no rules whatever in effect. This lack of rules in force is partly due to inaction on the part of State authorities and partly to the difficulty and expense each company encounters in preparing its own rules in any adequate form. The assistance of State commissions, operating companies, and electrical workmen has been freely given to the Bureau in this work, and the rules in their present form are offered to the public for criticism, discussion, and, so far as may be found desirable, for general adoption.

The scope of the safety rules includes all operation of, and work on or about, power and signal lines, and the electrical equipment of central stations, sub-stations, mines, and testing departments. The rules are divided into three parts. The first two parts consist of general rules which apply to the employer and to the employe respectively, and the third part comprises, under separate headings, those special rules which apply particularly to employes engaged in special classes of electrical work.

It is intended that employes should thoroughly familiarize themselves with all the general rules as well as those which relate solely to their own particular work.

While all the rules find application in the larger industrial or private plants or to utilities of moderate size, some do not

apply or apply less fully to the smaller organizations. It has seemed unwise to attempt to restrict the rules to those which are entirely applicable to the smallest organizations or to the simplest classes of electrical work, since the number of workers so employed is small compared with the total number to whose work uniform rules should apply.

The individual rules, suggested by conferees and resulting from careful comparisons and selections, have been subjected to careful general scrutiny to determine the necessity for each and its general applicability under varying conditions of operation. The different classes or workers to which the rules apply have been freely consulted. Concreteness, simplicity, and directness have been sought in the formulation of the rules.

After carefully considering each rule and retaining only those essential to the safety of operation, the grouping was made such as to facilitate reference.

The section for employers calls for the provision of employees with rules, diagrams and emergency instructions, their assignment to work according to their demonstrated abilities, and the division of responsibility among them in a definite manner so that danger may not arise through conflict on points of authority. The employer is also required to supply portable safeguards, to enforce general operating precautions, and to supply employees with forms for the adequate reporting of accidents. The final requirement is that the rules for employees be strictly enforced.

Rules for employees in general are subdivided into six groups. The first enumerates those general precautions the necessity for which seems obvious but the non-compliance with which is nevertheless responsible for many injuries. The second presents general operating rules, defining the duties and relations of those employees who direct others, and the operating methods by which safety is required. The third group prescribes the precautions for handling live parts under varying conditions of voltage and location. The fourth and fifth deal with the procedures for assuring the continued safety of work about normally live or moving parts respectively by avoiding all possible sources of misunderstanding in killing parts. The sixth group covers in some detail the procedure for making protective grounds and short circuits.

Special rules for employes comprise nine separate headings, covering the special hazards of work about electrical equipment in stations, at switchboards, about overhead lines, in arc lamp attendance, on underground lines, meter setting, testing, and in tunnel or mine work. Each class of worker is directed to familiarize himself also with the preceding general rules which apply to all classes of electrical employment. By this arrangement, a more adequate and convenient treatment has been realized without unnecessary repetition.

In a carefully prepared appendix the value of organized accident prevention work through safety committees, is emphasized as a means for reënforcing the effectiveness of safety rules. The report on this subject by the Accident Prevention Committee of the National Electric Light Association is briefly abstracted, and citations are made from the reported organizations and methods of several large and small electrical utilities.

The comment of those commissions, companies, and workmen, whose study of the subject has been closest, has been very favorable to the arrangement and substance of the rules given in this edition, and many have expressed a desire to adopt them or to utilize them in preparing similar codes. The requirements of different States and communities should be closely harmonized to secure the best results in reducing the accident toll of electrical service, and the results presented in this code should be advantageous in securing uniformity among the State codes of safety rules.

Great advantage will result to companies and workmen alike by the general adoption by the several States of a single standard set of safety rules, which can be revised in accordance with the progress of the art and the combined experience of all the companies and commissions of the country. Thus will every State and every company secure the advantage of the experience of all.

Where particular rules do not apply, their omission will of course cause no conflict in practice. If it is necessary for any State commission to adopt additional rules, that could be done at any time by special orders. This would be easier and less confusing than to have a different set of rules for each separate State.

Acknowledgment is made of the coöperation by national asso-

ciations, State commissions, company officials, and individuals. The conclusions reached by the Bureau of Standards from the combined experience of many of the most experienced companies and individual engineers and a thorough study of a large amount of literature and statistics are now offered with the hope that they will constitute a substantial contribution to the widely evidenced public need for a standard set of safety rules. It is believed that a material reduction in present life hazards to electrical workers may be realized by the general adoption and use of these rules.

GAS TESTING LABORATORIES.*

THIS circular contains suggestions as to location and equipment of gas-testing laboratories, a description of some of the accepted forms of apparatus, directions for the making of the various tests, and recommendations as to the interpretation of experimental results. It does not discuss the testing work necessary for good works control; it deals rather with methods which are intended for use in city or State official testing, or in works laboratories which are checked by city or State inspectors.

No attempt is made to fix on a single method to be used in every case, for it is not believed that uniformity of method is always necessary in order that the results of tests be considered standard. In each case as much freedom in choice of method is allowed as seems permissible; but the simplest procedure or apparatus with which satisfactory results can be had is given preference. The discussion is so arranged that an inexperienced man may utilize the information, but exactness of description has not been sacrificed in the effort to simplify the directions.

The full discussion of the influence of various conditions upon the results of tests and the theoretical consideration such as would properly accompany a publication of the results of a research are not given in the circular. Such full discussion will be found in the various sources referred to in the text.

Not all the methods which are recommended have been investi

* "Standard Methods of Gas Testing."—Bureau of Standards Circular No. 48, August 1, 1914.

gated in the laboratory of the Bureau, but every effort has been made to ensure that the use of such methods as have not been used at the Bureau has proven entirely satisfactory in the laboratories of experienced gas testers elsewhere.

The five principal subjects discussed are: measurement of heating value, candlepower determination, determination of impurities (hydrogen sulphide, total sulphur, and ammonia), taking of gas pressure records, and gas meter testing. Full operating directions, including a description of apparatus and precautions which must be observed, are included under each heading.

The Electron as a Vibrating Particle. ANON. (*Sci. Amer.*, cx, No. 20, 409.)—Herr Korn, after observations extending through twelve years, has established a mechanical theory of gravity and of reciprocal molecular effects; the main points of the theory are: Suppose an infinite and incompressible medium with very rapid vibrations, containing slightly compressible particles; such a system is capable of an infinite number of different vibrations. The mathematical investigation of such a system is not difficult, provided we assume that no whirlpools exist. The fundamental vibration will be a pulsation of the particles, and Newton's Law of Gravitation will express the reciprocal effects of these particles, due to this fundamental vibration. If we impose on the vibrating particles the condition of constant velocity of pulsation the electrons may be considered as such pulsating particles. In other words, we must conceive the electrons to oppose a very great resistance to any external action tending to modify their velocity of pulsation; it is also necessary to admit that these extremely rapid vibrations emit very little or no radiation. The duration of these vibrations is extremely great in comparison to the duration of all vibrations hitherto known.

Properties of Plastic Insulating Materials. E. HEMMING. (*Electr. World*, lxiii, 761.)—Insulating materials, which are suitable for molded work, are divided into a number of classes, according to the nature of the materials, such as fibre, rubber, porcelain, etc., of which the insulator is composed. The properties of insulators made of these different materials are stated in a table, which includes information under many various headings, and photographs are given showing a number of articles used for insulating purposes in lamps, plugs, switch-handles, rosettes, etc., which are made from molded materials. Other tables give figures showing the ohmic resistances and the dielectric strengths of molded insulations of different types.

Theory of Ocean and Primitive Continent Formation. E. BELOT. (*Comptes Rendus*, clviii, 647.)—On the earth and on Mars the ocean surface is much greater in the southern hemisphere than in the northern, while upon the moon the volcanic area is much more intense in the south than north, and it is considered that this points to a similar inequality of distribution of the water originally on the moon. This unipolar condensation of water on the earth, moon, and Mars may be easily explained if the relative translation of these three stars in the primitive nebula be assumed, the direction being that of the north part of their axes. This south-north translation had three principal effects: (1) The plastic terrestrial projectile became flattened in front and pointed behind. (2) The rotation, more retarded at the north than at the south pole, gave a twist to every relief in the sense of an easterly rotation of their southern parts. (3) At the exterior of the primitive terrestrial atmosphere, friction upon the nebula determined a general circulation in the sense north to south. This circulation has been demonstrated and investigated by Bossinesq in the case of a drop of water falling through a liquid. About the south pole the atmospheric circulation caused cold vertical currents to descend, and after heating at the earth's surface to ascend hot. Consequently the temperature fell below 364° (the critical temperature of water), producing an abundant condensation of water under the pressures then prevailing. The water currents then set up proceeded to weather out the configuration of the primitive continents. This theory is illustrated by numerous examples of present continental conditions, which in the author's opinion tend to confirm his views.

THE FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

NECROLOGY.

Arthur Otis Granger was born at Providence, February 14th, 1846, and died at his home in Cartersville, Georgia, on July 30th, 1914. He was the son of the Rev. Arthur Granger and Sarah Alcorn Rowan Granger. He was educated in the public schools of Philadelphia, and began his business career in a dry goods store in that city in 1858. In 1876, he organized the firm of A. O. Granger and Company, Engineers and Contractors, Philadelphia, Pa., and four years later he became President of the Granger Water Gas Company, also of Philadelphia. In his later years he was connected with numerous industrial enterprises. He was elected to membership of the Institute in 1877.

Horace Pettit died at his summer residence at Atlantic City, N. J., on August 13th, 1914. He was born in Philadelphia in 1860, and received his early education at the school of Dr. Faries and at the Cheltenham Military Academy. In 1879, he commenced the study of law and was graduated from the Law School of The University of Pennsylvania, four years later. Mr. Pettit was a member of The University Club, The Union League, The Racquet Club, and other organizations. He became a Life Member of The Franklin Institute in 1886, was elected to its Board of Managers in 1894 and served until 1910; he was a member of its Board of Trustees for several years.

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Pennsylvania Topographic and Geologic Survey. Richard H. Hice, State Geologist. Geology of the Broad Top Coal Field, Bedford, Fulton, and Huntingdon Counties, by James H. Gardner. Map, 43 x 45 inches, in colors. Harrisburg, State Printer, 1914.

A Fine Collection of Meteorites. ANON. (*Sci. Amer.*, cx, No. 23, 459.)—The American Museum of Natural History, in New York, has acquired this collection through the generosity of Mr. J. P. Morgan. It comprises the entire stock of meteorites which belonged to the unique establishment in Washington, known as "Howell's Microcosm" at the time of Mr. Howell's death, and includes representatives of 54 falls, weighing in the aggregate about 220 pounds.

Marble Shades and Reflectors. W. VOEGE. (*Elektrotechn. Zeitschr.*, xxxv, 199.)—The use of sheets of marble for diffusing light is proposed. Very thin sheets, 0.1 to 0.5 mm. thick, have been used for this purpose; *e.g.*, cemented to colored glass designs which it is desired to illuminate. For ordinary purposes the cost is excessive. A process has now been discovered by means of which thicker and cheaper plates, 3 to 20 mm. thick, can be used. They are first etched on both sides and then soaked in oil at high temperature and pressure, when they become more transparent than a similar plate of milk glass, and have excellent diffusing properties. It is expected that this material will prove useful for decorative light effects. A series of experiments is described that demonstrates that the marble transmits visible light better than the milk glass, but absorbs the infra-red rays to a greater degree.

CURRENT TOPICS

Heavy Chemicals in the United States. ANON. (*Oil, Paint and Drug Reporter*, May, 1914.)—The imports of bleaching powder in 1913 amounted to 30,800 short tons, compared with 37,120 tons in 1912, 41,450 tons in 1911, 50,500 tons in 1910, 45,700 tons in 1909, and 56,600 tons in 1908. Imports from England have decreased from about 30,000 tons in 1911 to 22,250 tons in 1913, while Germany supplies about 6000 tons annually. The output of American works amounts to about 90,000 tons, of which about 30,000 tons are exported. The output of caustic soda in 1913 reached about 190,000, of which about 20,000 tons were exported. The exports to Canada average about 15,000 to 20,000 drums per year. Arsenic was imported to the amount of 4130 tons in 1910, which dropped to 3340 tons in 1913. Imports from Europe have practically ceased, the only material source of foreign supply being Canada. The output last year in the United States was 2375 tons, and in 1912, 3141 tons.

Recording of Wireless Signals by Means of the Telegraphone. P. DOSNE. (*Comptes Rendus*, clviii, 473.)—The recording of wireless signals on a telegraphone wire or plate, as proposed by Simon and Reich, has been carried out by the author. A sound reinforcer constructed on the principle of that of Berget and Allard has its circuit interposed between the crystal detector employed and the telegraphone recording electromagnet.

The Most Powerful Magnet. ANON. (*Sci. Amer.*, cx, No. 23, 459.)—Probably the strongest electromagnet is produced by the new method successfully applied by Profs. Perot and Deslandres. Their idea is to take one of the strongest electromagnets of laboratory type with pointed pole pieces which already give a high value of the magnetic field, and then to put an extra coil around the air-gap between the poles so as to add considerably to the field. Such coil is made of thin copper strip and is cooled down as low as -30° C. by a current of oil, so that a remarkably heavy current can be put into the coil without burning it; *e.g.*, it will stand a current density of 1800 ampères per square mm., using a 0.2 mm. strip. Such a coil is put on a Weiss electromagnet which carries the usual coils and gives 41,000 gauss for the magnetic field strength. Putting on the 30,000 ampère-turns of the new coil brought up the field strength to 51,000 gauss, and it was only the lack of current supply that prevented running as high as probably 60,000 gauss, so that a most powerful field can thus be obtained.

Longest Rope Railroad. ANON. (*Amer. Mach.*, xl, No. 26, 1115.)—What is calculated as the longest rope railroad in the world is to be operated in India. It is 75 miles in length, and will connect the rich country in the vale of Kashmir with the plains of the Punjab over the Himalayas. The present longest rope railroad is 22 miles, situated in the Argentine. The sections will be five miles long, and most of the spans will be 2400 feet. The steel towers, some of which will be 100 feet high, will be braced, and double $1\frac{1}{2}$ inch cables, 9 feet apart, will carry the steel cars. The carrying capacity of these cars will be about 400 pounds each.

The Surface Tension of Soap Films. G. F. C. SEARLE. (*Cambridge Phil. Soc. Proc.*, xvii, 285.)—This gives an account of some methods employed at the Cavendish Laboratory for the measurement of the surface tension of soap solution. The methods described are: (1) The *torsion balance method*, in which a rectangular frame of wire is dipped into a soap solution and the pull of the film is measured by the aid of a simple torsion balance. The value of the surface tension was found to be 27.22 dynes/cm. by this method. (2) The *thread method*, in which the surface tension is deduced from the curvature produced in flexible threads dipped in the solution. The surface tension by this apparatus was 27.17 dynes/cm. (3) The *viscosity potentiometer method*, in which the pressure excess due to a spherical soap film is measured; the result of this was 25.19 dynes/cm. (4) The *buoyancy method*, which depends upon the difference of density between cold and hot air at the same pressure. By this method the surface tension was found to be 27.07 dynes/cm.

The Choice of a Trolley Wire. G. H. MCKELWAY. (*Electr. Rly. Journ.*, xliii, 647.)—Points out the matters that should be taken into consideration in determining the most economical size of trolley wire to use in any particular case; the cost of material and labor is based on American rates.

The Greis Smoke Preventing Device. ANON. (*Amer. Soc. Mech. Engin. Journ.*, xxxvi, 649.)—The principle of the apparatus is that of a secondary air supply, regulated and controlled by the opening and closing of the furnace doors. In connection with the use of this device, there is a subsidiary apparatus which produces a mixed steam- and water-fog in the flues, smokestack or chimney. This causes the soot and dust particles to become saturated with moisture, and to fall by their own weight, before they can escape into the atmosphere. The process of washing the hot gases flowing through the smokestack continues as long as one of the smoke-consuming devices on the boilers is in operation. The apparatus does not act until the fire-door is opened; this marks the beginning of the period when the conditions are particularly favorable to an evolution of black smoke.

Aczolling Pole Timber. ANON. (*Elect. Rev.*, lxxiv, 85.)—This describes the preservation of timber by aczol, which is a mixture of metallic ammoniates with an antiseptic acid containing phenols and naphthalenes—the essential preservative elements of creosote. The compound is claimed to have especially great and enduring preservative value. Owing to the solubility of cellulose and vasculose in aczol, the surface layers of the fibres and tissues of the wood treated are coated and cemented together by a combined chemical and physical action which yields secondary and perfectly stable compounds. As sold, aczol contains 15 to 30 per cent. of reinforced phenols and the equivalent of 30 per cent. of copper and zinc salts. This concentrated material is estimated to have 150 times the preservative power actually required to effect sterilization. Hence and because the preservative elements are fixed permanently in the aczol-cellulose compounds, a very dilute solution may be used. Timber to be buried or exposed continuously to weather may be painted with a one in five or six solution of aczol in water. Impregnation is preferable and must be employed for telegraph poles. Injection is by simple immersion for two or three weeks or more rapidly by pressure; cold solution is used. The weight of the timber is hardly increased by treatment; the wood is not rendered objectionable nor dangerous in any way, but is appreciably strengthened, and it can be painted or polished after treatment. By regulating the strength of solution used, timber may be made waterproof or flame-proof. None of the ingredients of aczol corrodes iron or other metals, nor do they reduce the insulating value of wood.

Resistometric Studies of Some Iron-Nickel Alloys. A. P. SCHLEICHER and W. GUERTLER. (*Z. Elektrochem.*, xx, 237.)—Wires of three alloys containing respectively nickel 35.25, 30.6, and 25.2 per cent. were heated *in vacuo* in an electric furnace, and their electrical resistance measured at different temperatures. There was a pronounced discontinuity in the temperature-resistivity curve at about 420° C. for the 35.25 per cent. alloy, and at 700° C. for 30.6 per cent. alloy. The 25.2 per cent. alloy in its original condition gave abnormally low values, but the resistance became higher with each successive heating, until the wire became stabilized, and gave a regular curve with a discontinuity at 900° C. The significance of these results is discussed in connection with the constitution of the alloys and their magnetic properties.

Illuminating Engineering Society.—The Eighth Annual Convention will be held in Cleveland, Ohio, September 21st to 25th, inclusive. Papers will be presented by J. R. Cravath, Herbert E. Ives, M. Luckiesh, E. J. Brady, and many others. The subjects are quite varied and cover all problems of illumination, including the physics of the subject. The headquarters of the Society will be at The Hollenden Hotel, where reservations may now be made.

Durability of High-grade Papers. W. HERZBERG. (*Papierfab.*, 478.)—Hjelmstätter exposed a number of papers, both animal-sized and rosin-sized, to full sunlight from June to August, and then tested the deterioration produced. In all the paper, including even the tub-sized hand-made papers, the exposure to light and air produced marked deterioration in the resistance to folding, in many cases this fell to 5 per cent. of the original value. The sizing resistance to ink had disappeared in all cases. The paper belonging to normal class 1, both the animal-sized papers and those doubly sized (both animal and rosin sizes), showed only a slight darkening in color; the rosin-sized samples were much discolored. It was concluded that the deterioration in resistance to folding produced by exposure was in some way connected with the destruction or decomposition of the sizing. From tests in which papers were steeped in solutions of aluminum sulphate, potassium sulphate, and aluminum acetate, and then exposed to light, the author concluded that the deterioration was brought about by the presence of aluminum sulphate; aluminum acetate had no bad effect. Herzberg points out that in the tests recorded, those papers which contained only very small quantities of aluminum salts proved no more resistant than those samples containing comparatively large proportions, so that a directly injurious influence of aluminum sulphate cannot be inferred. The fact that the introduction of a large excess of this salt into the paper was found to be injurious does not prove that papers containing normal quantities are similarly affected.

The Clinkering of Coal. O. W. PALMENBERG. (*Mech. Eng.*, xxxiii, 194.)—One of the most troublesome features in the combustion of coal is due to the production of clinker. This influences the rate of combustion and the cost of maintenance, especially where automatic stokers are used. A coal may clinker so readily under certain conditions that it becomes unfit for use, irrespective of its fuel value. It is therefore of the greatest importance to know whether a coal will clinker under the conditions for which it is required. The determination of the clinkering properties of a coal, that is, whether its ash will fuse at a low temperature, has been carried out in several ways; and many authorities have considered that an analysis of the ash, or determination of the iron in the ash, or of the sulphur in the coal, would furnish the information desired. To show that there is no relation between the clinkering quality of a coal and the sulphur or iron content, the author has made an independent investigation of the problem. Analyses of the ash, together with the fusing temperature determinations on a wide range of coals, show that no conclusions can be drawn from a chemical analysis. It may be noted that some coals have ash of like iron contents and variable fusion temperature; others have ash of like fusion temperature and variable iron content. It would appear, therefore, that there is no relation between the percentage of the

various constituents of the ash and the fusing temperature. Hence a chemical analysis is of no value for arriving at a judgment as to the clinkering quality of a coal. The fusion temperature of the ash ought, therefore, in the future to displace the sulphur determination in coals used for steaming purposes, and this change will readily show the fallacy of buying and selling coal on an analysis basis, where specifications are used containing sulphur tables penalizing beyond a certain guaranteed amount of sulphur. It has been quite a common practice to place 1.5 per cent. of sulphur as a limit, and to penalize the seller as much as 4 cents per ton for every 0.25 per cent. of sulphur above 1.50 per cent. The injustice of this practice is evident, as it often happens that coals with a high sulphur-content are extremely high in heat value, and do not clinker readily. Since the sulphur has no appreciable effect upon the metallic parts of the furnace, it need not be considered in the selection of a coal for steaming purposes. To arrive at the value of a coal for this purpose it is therefore just as essential to make the fusion test of the ash, as it is to make the calorimetric determination. If these two determinations are made, an explanation is readily found as to why two coals of apparently like proximate analyses give entirely different evaporation when fired under like conditions.

Production of Steel Direct from Ore. E. HUMBERT and A. HETHEG. (*Iron and Steel Inst.*, May, 1914.)—Tests were made with Swedish and Brazilian iron ores in a Héroult electric furnace of six tons capacity, using coke as fuel. The conclusions reached are: that the economic manufacture of steel from ore is practicable; that the product, on account of its comparative freedom from hydrogen, nitrogen, and other impurities, is superior, especially in toughness, to steel obtained by present methods; that the electric furnace employed should be of a type permitting violent ebullition of the bath without overflowing; that either charcoal, coke or anthracite may be used as fuel; and that anthracite electrodes will probably be most economical.

Demolition of the First Skyscraper. ANON. (*Sci. Amer.*, cx, No. 18, 359.)—To make way for a larger structure, there has recently been demolished a ten-story tower building at 60 Broadway, New York City. The building was erected in 1889 and has been in service about 25 years. Naturally the condition of its framework was of considerable interest to architects and engineers. The frame consisted of cast-iron columns and wrought-iron floor beams. The floors were of flat arch terra cotta construction. The framework was found in excellent condition, the wrought-iron beams showing a practical absence of rust, and the cast-iron columns, with a three-inch cast-iron shell around them for fire protection, showing only a few localized patches of rust, and heavy rusting only at a few special points.

Observations on the Burning of Porcelain. R. REINDEL. (*Spreschsaal*, xl, vii, 285.)—The behavior of an experimental oven was studied by the help of Seger cones, a pyrometer, a manometer, and the analyses of the oven gases. The readings of the pyrometer showed higher temperatures than those indicated by the cones, the difference amounting sometimes to 100° C. at the commencement of the heat and diminishing at later stages. Temperature curves were not regular in their ascent, but dropped at every addition of fuel. The draught also varied from 25 to 50 mm. according to the condition of the fire. Analyses of the fire gases were conducted at cone *09a*, the point at which they begin to influence the character of porcelain. A content of 3 to 5 per cent. of carbon monoxide is necessary at this temperature, but at cones 8 or 9, one per cent. is sufficient to maintain the reducing character of the oven atmosphere so far as regards porcelain.

Possible Cause of Explosions in Coal Mines. W. A. D. RUDGE. (*Nature*, xcii, 660.)—A cloud of dust suddenly projected against an insulated wire may charge it up to such a potential that sparks several cm. in length are produced; the material of the dust does not much matter, except as to the sign of the charge. Experiments made in Ludlow Pit at Radstock, the observer walking behind a train of wagons with a Wulf electrometer provided with a radium-tipped collector, yielded potentials of 280 volts; but no sparks were observed in the mine. The coal dust in a mine is rarely pure, however, laboratory tests showed that coal dust covered with flue dust from the boilers would not charge a conductor to a sparking potential in this way, whilst pure coal dust and pure flue dust did, the two charges being of opposite signs.

New Reagent for Etching Mild Steel. W. ROSENHAIN and J. L. HAUGHTON. (*Iron and Steel Inst.*, May, 1914.)—The reagent is composed of ferric chloride, 30 gram.; concentrated hydrochloric acid, 100 c.c.; cupric chloride, 1 gram.; stannic chloride, 0.5 gr.; and water, 1 litre; and it is necessary that the surface of the metal to which it is applied be perfectly clean. The reagent deposits a thin film of metallic copper. On hardened steels, especially of low and moderate carbon contents, the results were similar to those obtained with picric acid, etc., but the outlines of the copper films were very sharp, especially on martensite; troostite and sorbite were darkened. On practically pure carbon steels with the usual pearlite-ferrite structure, the effect was the reverse of that obtained by picric acid, etc., the pearlite being unaffected. The reagent proved specially useful for revealing the distribution of phosphorus in mild steels, giving results which compared favorably with those obtained by Stead's method of heat-tinting. In addition to the typical etching effect, discolored patches surrounding small black pits were frequently observed, usually grouped around a slag-enclosure.

Atmospheric Pressure at Great Heights. ANON. (*Sci. Amer.*, cx, No. 18, 359.)—It is usually supposed that at great heights the pressure of the air is almost negligible, but the application of an ingenious method indicated by Ramsay gives interesting results. He asserts that the green line characteristic of the spectrum of krypton remains visible under a pressure of 0.000035 mm. of mercury. Now this green line is found in the spectrum of the aurora borealis, and it seems to be well established that this exists frequently at altitudes between 100 and 200 miles, and even sometimes up to nearly 500 miles. But krypton is one of the heaviest gases in our atmosphere. It would seem, therefore, that the density of the air at these altitudes is by no means negligible, as whatever the cause may be of the presence of krypton there, it could not remain there unless the air possessed an appreciable density.

Core for Babbitt. ANON. (*The Metal Ind.*, xii, No. 6, 252.)—In castings of babbitt metal it is often necessary to core out some of the parts. A very good core is made of salt and glue. Mix just enough glue into the salt to make a stiff paste, which is shaped or molded in a core box and allowed to harden. This kind of a core can be removed from the casting by soaking it in warm water.

Gyroscopic and Gyrostatic Action. ANON. (*Amer. Mach.*, xl, No. 26, 1128.)—The difference between gyroscopic and gyrostatic action is, briefly, this: Action is gyroscopic when precession is quite free, or controllable at will; and gyrostatic when the axis of rotation is fixed relatively to some large structure. Gyrostatic action is usually incidental and undesirable; gyroscopic is the salient feature of the gyroscope in its various adaptations.

Porosity of Iron. W. H. PERKINS. (*Chem. Soc. Journ.*, cv, 102.)—Perkins repeated and extended Friend's experiments on the absorption of caustic alkalis by iron. Experiments carried out in platinum dishes with sodium, potassium, barium, lithium, and ammonium hydroxides show that distinct traces of alkali are retained by iron and by other metals. Their extraction is a slow process of diffusion and is not hastened by shaking.

Water-proofing Concrete. ANON. (*Sci. Amer.*, cx, No. 21, 425.)—The United States Army engineers have long used the following mixture in water-proofing cement: One part cement, two parts sand, three-quarters of one pound of dry powdered alum to each cubic foot of sand. Mix dry and add water in which three-quarters of one pound of soap has been dissolved to each gallon. This is nearly as strong as ordinary cement, and is quite impervious to water, besides preventing efflorescence. For a wash, a mixture of one pound of lye and two pounds of alum in two gallons of water is often used.

The Kieselguhr Industry. P. A. BORCK. (*Metall. and Chem. Engin.*, xii, 109.)—This article treats of the properties of kieselguhr, its occurrence at Lompoc, California, and other places, and its treatment. Natural blocks can be obtained by sawing the material; these blocks are fairly strong, have a high insulating value, stand heat and cold well, except as to a slight shrinkage, and melt at 1610° C. Light-weight kieselguhr bricks are produced by properly burning the material; they insulate well up to red-heat, but shrink at high temperatures, and must be protected against sudden changes of temperature. They are recommended as backing for more refractory bricks.

Repeated Use of Lubricating Oil after Filtration. G. F. FENNO. (*Min. and Eng. World*, xl, 835.)—In an installation fitted with a Richardson central oiling and filtering system, a high grade mineral oil was supplied continuously to the bearings, and, after filtration and removal of water, was used over and over again. After 18 months the oil was found to have increased somewhat in specific gravity and viscosity, owing to admixture with some of the cylinder oil. The fresh oil showed a slighter lower coefficient of friction on low-bearing pressures, while the friction coefficient of the filtered oil was lower on higher-bearing pressures, but the difference was so small as to be negligible under working conditions. The saving in cost of oil with a plant using two Richardson filters, each taking about 75 gallons per hour, is estimated at \$2000 per month.



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THE RECOVERY OF GAS WORKS BY-PRODUCTS.*

BY

C. C. TUTWILER, A.B., M.S.,

Consulting Chemist, Philadelphia.
Member of the Institute.

THE term "by-product" may, I think, best be defined in the words of a well-known writer on the subject, Professor Chas. E. Munroe, who refers to such materials as "substances or results obtained in the operation of a specific process in addition to the substance or result primarily sought."

The foregoing definition is much to be preferred to the commonly accepted one wherein they are referred to as "secondary products," for no reference is here made either directly or implied to their commercial value or importance, and instances may be recalled where the primary product finally became of secondary importance to a by-product, which in the early stages of the operation was considered to be of little or no value.

It is but natural, therefore, that investigations having as their object the recovery and utilization of by-products in any field of industrial endeavor, are apt to prove interesting, if not always profitable. This is particularly true of gas works by-products, owing to the fact that some of the most important and useful substances employed in medicine and the arts are derived from residuals produced in connection with the manufacture of illum-

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inating gas. Some idea of the diverse character of these compounds can be gained from Figure 1.

The volume and importance of these so-called gas works residuals is such, that their refinement and exploitation have given birth to new industries, producing in their turn primary products with the usual accompaniment of secondary by-products; and it perhaps may be truly said that there is hardly a branch of chemical manufacture that does not require and use some chemical having its origin in by-products from the destructive distillation of coal or oil either in the process of the manufacture of illuminating gas or in modern by-product coke ovens having, generally, as their primary object the manufacture of metallurgical coke.

Much has been written upon this class of materials, and it would be unwise and perhaps tiresome to you to attempt more than a brief review of the subject as a whole. I shall also confine my remarks to gas works by-products, as those produced in coke ovens are of quite similar composition; and, too, the early history and development of this industry is inseparably interwoven with the history and development of the illuminating gas industry.

The subject treated refers especially to tar, ammoniacal liquor, and coke, but other less important associated by-products will also be touched upon. The physical characteristics of these substances are well known to you and need no special description at the present time. The products derived from them will, however, be considered, following a brief historical review of the status of these materials in relation to the gas business and their method of recovery in a modern gas plant.

Historical.

Although it was early recognized by Winsor (1803) and other gas engineers of his day, that coke, as a domestic fuel, was of equal or nearly equal value as the gas; tar and ammoniacal liquor represented at the start and for a number of years thereafter, an intolerable nuisance, and even as late as 1841, a description of an apparatus devised "for most effectually converting into carburetted hydrogen gas the tar and ammoniacal liquor produced from the coal in the retort as they, in a state of vapor, are on their passage to the hydraulic main" was considered of sufficient importance to be specially mentioned in the preface to a

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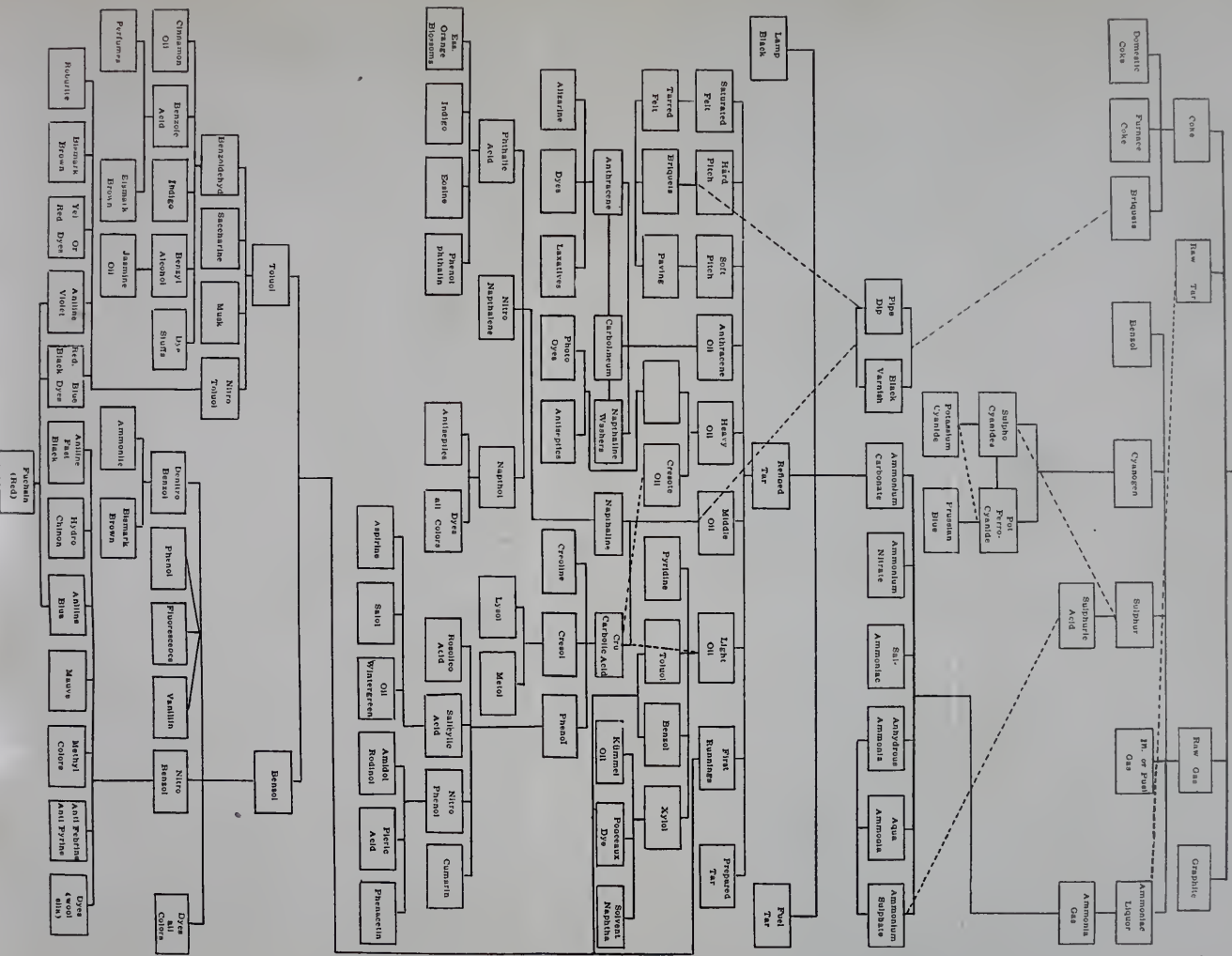


Chart illustrating the products and by-products of coal.

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treatise on "Gas Lighting" by a civil engineer of the day—Thomas S. Peckston—and to be dealt with at length in the volume cited.

The necessity for delivering to the consumer a gas free from such impurities as tar and ammonia, as well as for manufacturing and distribution reasons, made it imperative then, as it is to-day, that they be removed from the gas, whether or not they could be disposed of at a profit, it being out of the question to attempt to distribute gas containing more than a very minute trace of ammonia or tar. In the early days of the gas industry, therefore, the engineer was more concerned with the more or less complete removal of these impurities from the gas, than he was over the recovery of them in salable form.

Prior to the beginning of the Eighteenth Century, very little attention appears to have been given to the tar formed in connection with the heating of coal. It is of historical interest, however, to note a patent granted, in 1681, to Joachim, Becher and Searle, describing a "new way of making pitch and tarre out of pit coale never before found out or used by others." One of them, a German chemist, Johann Joachim by name, has the following to say in reference to the subject:

"In Holland they have peat and in England pit-coals (Steinkohlen); neither of them is very good for burning, be it in rooms or for smelting. But I have found a way, not merely to burn both kinds into good coal (coke) which not any more smokes nor stinks, but with their flame to smelt equally well as with wood, so that a foot of such coal makes flames 10 feet long. That I have demonstrated with pit-coal at the Hague, and here in England at Mr. Boyle's also at Windsor on the large scale. In this connection it is noteworthy that, equally as the Swedes make their tar from firwood, I have here in England made from pit-coal a sort of tar which is equal to the Swedish in every way for some operations is even superior to it. I have made proof of it on wood and on ropes, and the proof has been found right, so that even the King has seen a specimen of it, which is a great thing in England, and the coal from which the tar has been taken out is better for use than before."

In addition to the foregoing, mention is made of this substance by Clayton in 1738, de Gensanne in 1768, and Stauf in 1771, and in 1781 a patent was granted to the Earl of Dundonald covering "A method of extracting or making tar, pitch, essential oils, volatile alkali, mineral acids, salts, and cinders from pit-coal." It will be seen from the foregoing that this substance tar

merited the attention of investigators some 200 years ago, but its manufacture was never carried out to any great extent until it appeared as a by-product in connection with the manufacture of illuminating gas, which was launched toward the end of the last century, at practically the same time, by a Frenchman named Lebon and an Englishman named William Murdoch. It appears that to Murdoch and his pupil, Clegg, must be given the credit for placing the gas industry on a firm basis. In 1815, Accum demonstrated that the quality of the tar was considerably improved by boiling, and that a valuable light oil, which could be used for a turpentine substitute, was recovered therefrom. In 1838, a marked impetus was given to the distillation of tar by the development of the suggestion on the part of Bethell that it could be used to good advantage in the preservation of timber. The industry was further advanced by the discovery of benzene in these light oils by A. W. Hofmann, in 1845, but it was the epoch-making discovery by an English chemist—William Henry Perkin—in 1856 of mauve, the first of the aniline colors, and that it could be procured in abundance from products obtainable from coal tar, that lifted this material at once from the ignominious position that it had long held to the important one which it has enjoyed ever since, not only as a source for aniline colors, but for numerous other products of scientific and commercial importance as well.

It might be gathered from the foregoing that about this time the troubles of the producers of tar were in a fair way to be overcome. Such, however, was not the case, owing to the very rapid increase in the amount of illuminating gas made and the incidental increased production of tar. Samuel Hughes, in his book on Gas Works Practice, published in 1853, states that "both tar and ammoniacal liquor are sold, the usual price for tar being 1 penny per gallon and for ammoniacal liquor 1 farthing per gallon." These prices are not much lower than obtained to-day, but it should be remembered that the amount of tar produced at this time was small and that a new industry was just being opened up. That the market was soon oversupplied is indicated, from this time on to but a comparatively recent period, by the number of patents that were taken out with the idea of opening up new uses for tar, and the never-ceasing search of the gas engineer for some outlet for a material which not only yielded him

no profit but represented a very serious inconvenience. As illustrating the condition existing in this country in the early 60's, the following letter addressed to the Editor of the *American Gas Light Journal* is of interest:

"The accumulation of tar at the various gas manufacturing establishments throughout the country is of such an amount as to put the ingenuity of those having it in charge to the test to know what to do with it. But a few years since and the demand could not be supplied; now it has become a drug on the market, no one wanting to purchase. The corporate authorities of cities and towns are taking the subject in hand, prohibiting the emptying of it into streams convenient to works—its mixture with the waters preventing cattle from drinking as well as rendering it unfit for domestic and culinary purposes. Is there no plan that can be devised to make the article of coal tar useful in its application to some purpose by which the whole or part of it might be used—or destroyed that it may not become a nuisance to the neighborhood? I trust that this article will be the means of eliciting from some of your correspondents some suggestions respecting the tar as will, in the end, result in something useful."

It does not appear from an examination of the issues of the *Journals* appearing during the next few years, that a satisfactory answer was given to the inquirer, but there is abundant evidence to show that the subject was under investigation continually, a favored outlet being born of the belief in the minds of many that the tar was an unnecessary by-product and could be converted into gas.

Those of us who have spent a good part of our lives in the gas industry—some of it directed along these unpromising but alluring lines—read with interest an excerpt from an article appearing in the *Gas Light Journal* of 1860, as follows:

"For more than thirty years coal tar has been twisted and turned in every way to give up its latent store of gaseous luminosity. It has been distilled at high heats and at low heats; with steam and without steam; with coke and without coke; with wholly spent charge of coal and the half spent charge; with iron wires, hoops and chains, with scrap iron, charcoal coals, brickbats, lime, and clay, and in fact with everything at all likely to assist in its decomposition and give rise to that all desired conclusion—the economical production of illuminating gas. At length we find after an enormous expenditure of time, talent, and money, that practically the thing can not be done to pay—consequently it can not be done at all."

Since 1860 the development of the tar distilling industry has been enormous, new uses being found for the products obtained therefrom, chiefly along the lines of wood preservation and in the

preparation of pitch for roofing purposes, and for the last 20 or 30 years it has been comparatively easy for gas works to dispose of their products, if of fair quality, at a price which while low at least enables them to rid themselves of it at a profit.

I am indebted to a paper by S. R. Church, Manager Research Department, Barrett Manufacturing Company, and read before a recent meeting of the Southern Gas Association, for the following history bearing upon the development of the tar distilling business in this country:

"A very considerable business in the refining of the by-products of the gas works had sprung up and flourished before the introduction of by-product ovens. So far as the writer has been able to learn, this industry, based on gas works tar and ammonia liquor, was developed independent of the gas works engineers and managers, by a number of entirely separate concerns and individuals. Among the pioneers in the industry were Cyrus M. Warren and his brothers.

"Cyrus M. Warren was educated at Harvard University, and on the advice of Professor Agassiz, went to Germany, where he studied chemistry under Liebig, and became interested in coal tar. Mr. Warren was possibly the pioneer in the industry in this country.

"In the early sixties Samuel Page started distilling coal tar in Boston, and shortly afterwards his brothers, under the style of Page Brothers, started business in New York City, where they were succeeded by Page, Kidder and Fletcher. Mr. I. D. Fletcher, now President of the Barrett Manufacturing Company, became associated with the Pages early in the sixties. At about the same time Mr. Fletcher's brother established what was probably the first tar refinery in the South, at New Orleans.

"Major S. E. Barrett and his associates, who started in Chicago, were among the pioneers of the same industry, as were Levi L. Wilcutt and Joseph C. Storey of Boston, Chapman and Soden of Boston, and A. T. Perry, who was associated with Cyrus M. Warren, and later went to Cleveland, where he established a tar refinery.

"Others who were engaged in the industry in the early times were: W. H. Childs of Brooklyn, Michael Ehret of Philadelphia, and P. S. Marquis of St. Louis."

Such briefly is the history of one of these important by-products, and no less interesting and of equal value is another—ammoniacal liquor from which is produced most of the ammonia of commerce.

The salts of ammonia have been known from the earliest antiquity. Pliny, Hippocrates, and Discorides made frequent mention of "ammoniakon," and Herodotus refers to "hals ammoniakos," as do other authors up to the sixth century. The name ammonia appears to have been given to it by Berthollet, to

whom credit must also be naturally given for determining its composition.

While ammonia occurs in combination in many natural occurring substances, it is from gas works liquor that the bulk of the supply is now obtained. Numerous observers demonstrated that it could be obtained from the destructive distillation of animal refuse, peat, vinasse, etc., but time does not permit a review of the investigation and research work which has been carried out on this product by chemists and others from the earliest days of the gas business. It appears, however, that there was never a time when it was regarded as an undesirable product such as was tar, because its value as a fertilizer was early recognized, and in this direction it could be employed in unlimited quantities.

Statistical.

As illustrating the enormous increase in product of ammonia and tar in this country during the past ten years, the following table taken from the Mineral Resources of the United States, 1912, is of interest.

PRODUCTION OF GAS, COKE, TAR AND AMMONIA, AND VALUE THEREOF, AT COAL GAS WORKS AND BY-PRODUCT COKE OVENS IN THE UNITED STATES, 1903-1905, 1907-1908, AND 1912.

	1903		1904	
	Quantity	Value	Quantity	Value
Gas sold..... 1000 cu. ft.	31,049,462	30,315,776	34,814,991	32,090,998
Coke.....short tons	3,941,282	13,634,095	4,716,049	14,693,126
Tar.....gallons	62,964,393	2,199,969	69,498,085	2,114,421
Ammonia (reduced to NH ₃).....pounds	17,643,507	1,291,732	19,750,032	1,487,196
Ammonium sulphate.....pounds	12,400,032	389,028	28,225,210	771,995
	1905		1907	
	Quantity	Value	Quantity	Value
Gas sold..... 1000 cu. ft.	40,454,215	32,937,456	54,819,685	36,462,304
Coke.....short tons	5,751,378	18,844,866	8,093,144	30,332,644
Tar.....gallons	80,022,043	2,176,944	103,577,760	2,651,527
Ammonia (reduced to NH ₃).....pounds	22,455,857	1,728,254	37,560,858	2,601,057
Ammonium sulphate.....pounds	38,663,682	997,452	48,882,237	1,525,472
	1908		1912	
	Quantity	Value	Quantity	Value
Gas sold..... 1000 cu. ft.	53,561,811	37,227,901	89,693,372	36,681,884
Coke.....short tons	6,253,125	21,507,045	12,490,757	48,380,009
Tar.....gallons	101,261,829	2,537,118	134,796,438	3,802,047
Ammonia (reduced to NH ₃).....pounds	30,615,835	2,065,169	51,527,074	4,776,386
Ammonia sulphate.....pounds	44,093,437	1,322,807	99,070,777	3,740,075
Ammoniacal liquor.....gallons	.....	.....	35,242,549	1,002,807

It will be seen that both the tar and ammonia production more than doubled during the above mentioned period.

As might be gathered from the foregoing, the proper recovery of these by-products now receives almost, if not quite as much, attention as the proper manufacture of the primary product, and the modern gas engineer must design his plant with the dual object in view of producing a gas satisfactory from an illuminating and calorific standpoint and commercially pure, and at the same time give due consideration to a proper conservation of the by-products in a form best suited for their most profitable utilization.

Recovery.

Having briefly reviewed the history of the two principal products under consideration, I will now endeavor to explain the method by which they are recovered in a modern gas plant and made suitable for the market, and since quite a considerable portion of these by-products are recovered at almost every step in the process, clearness requires that the ordinary methods of gas manufacture be briefly considered along with a more detailed account of the special apparatus employed. It will suffice also to consider only the manufacture of coal gas which yields both tar and ammoniacal liquor, whereas tar alone is produced as a by-product in the manufacture of water gas.

It should be stated here that coal gas is usually produced from a high volatile coal containing from 35 to 38 per cent. of volatile combustible matter. A typical analysis of such a gas coal, both proximate and ultimate, is as follows:

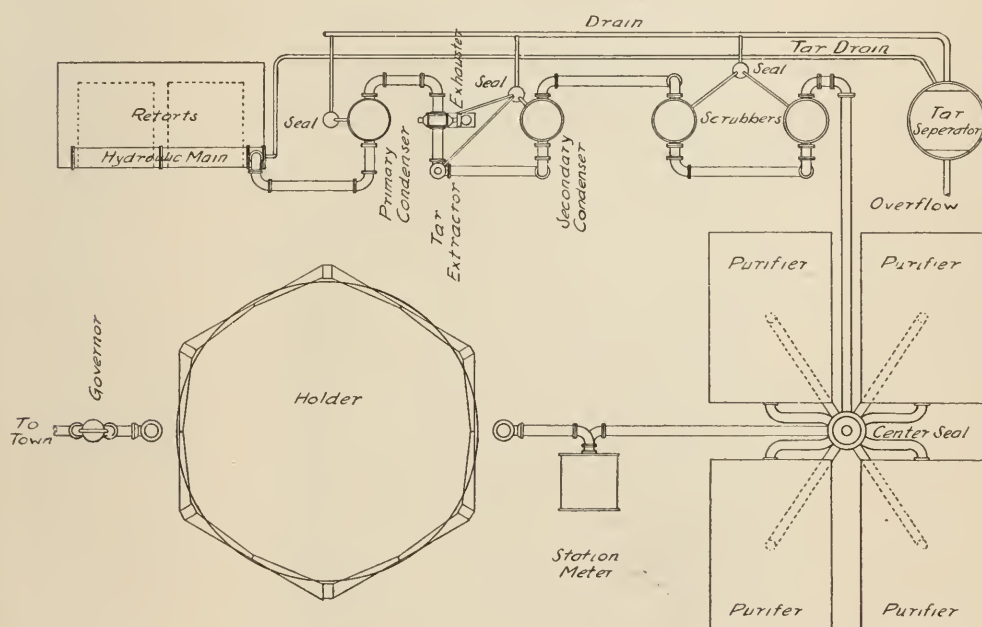
<i>Proximate</i>		<i>Ultimate</i>	
Moisture.....	2.2 per cent.	Carbon.....	78.4 per cent.
Volatile combustible.....	38.1 per cent.	Hydrogen.....	4.8 per cent.
Fixed carbon.....	53.2 per cent.	Nitrogen.....	1.5 per cent.
Ash.....	6.5 per cent.	Sulphur.....	1.3 per cent.
		Oxygen.....	7.4 per cent.
		Ash.....	6.6 per cent.

The manufacture of illuminating gas in a modern gas plant may be divided into three operations; the first involving the generation of the crude gas from the raw material; the second, its purification; and the third, its distribution.

In Figure 2 is shown a plan layout of a coal gas plant provided with apparatus necessary for the generation and proper purification of the gas and the recovery of the by-products in


their crude form. Basically, there has been very little change in the general methods of coal gas manufacture, by the horizontal retort method, since the beginning of the industry. The various pieces of apparatus have, however, been improved and in some few instances supplanted by others of a radically different type. The practice, however, of cooling the gas by means of air- or water-cooled condensers for the purpose of freeing it from the greater portion of its suspended tar before it enters the ammonia washers has generally been regarded as essential and has been, up to very recent years, universally followed.

FIG. 2.



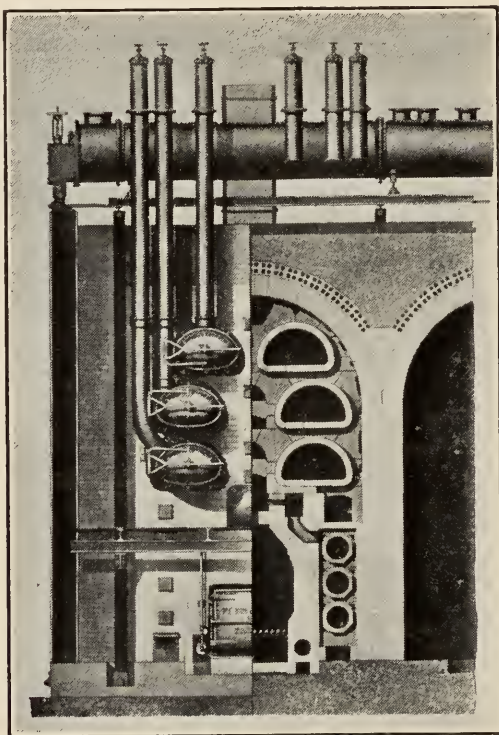
Arrangement of coal gas plant.

In Figure 2, the battery of retorts represents the generating apparatus. Following this is the condensing and scrubbing apparatus and the four-box purifying system. The functions of these various pieces of apparatus and the part they play in the production and recovery of the two principal by-products will be more clearly understood from a consideration of their construction in more or less detail.

Figure 3 shows a bench of six retorts, although a larger number is quite frequently employed. The illustration shows three of the retorts with mouthpieces and stand pipes removed. It will be seen that they are  shaped in cross section. They

are however sometimes elliptical or circular and even rectangular. The ordinary stop-end retort is about 9 feet long, 26 inches wide, and 15 inches high, and is capable of handling a charge of from 350 to 400 pounds of coal every 4 hours, the retorts being maintained at a light cherry-red heat by means of the furnaces placed within the retort setting. The furnaces are usually fired with a portion of the coke remaining in the retort after the gas is expelled. The gas derived from the volatile portion of the coal,

FIG. 3.



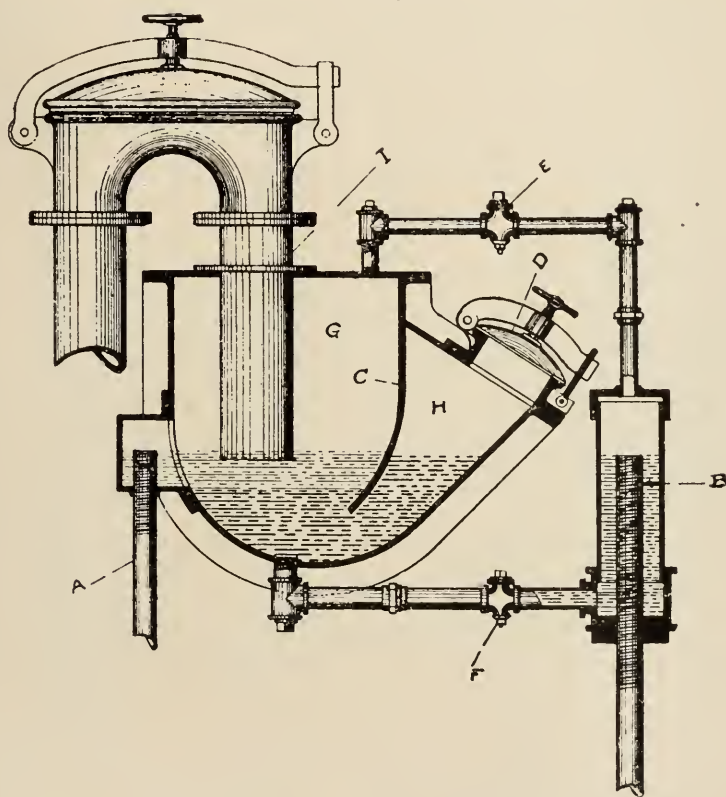
Coal gas retorts.

risks through the stand pipes and passes through dip pipes into the hydraulic main, loaded with tar, and water vapor carrying ammonia and other impurities in solution. The ends of the dip pipes are sealed in ammonia liquor maintained at a constant level in the hydraulic main (see Figure 4). This liquor, which floats on the surface of the heavier tar lying in the bottom of the main, is deposited in an amount sufficient, not only to maintain the seal at all times, but an excess is produced which is carried away to the receiving tank, by way of an automatic overflow, the

tar passing out of the main to the tar well through an overflow which may or may not be automatic.

The passage of the gas through the seal in the hydraulic main reduces its temperature to 160° F. or thereabouts. This reduction in temperature is the chief cause of the precipitation of a large quantity of water vapor, containing ammonia in solution, and tar. Generally about 60 to 70 per cent. of the total tar produced is deposited at this point together with from 10 to 15

FIG. 4.



Cross section of hydraulic main.

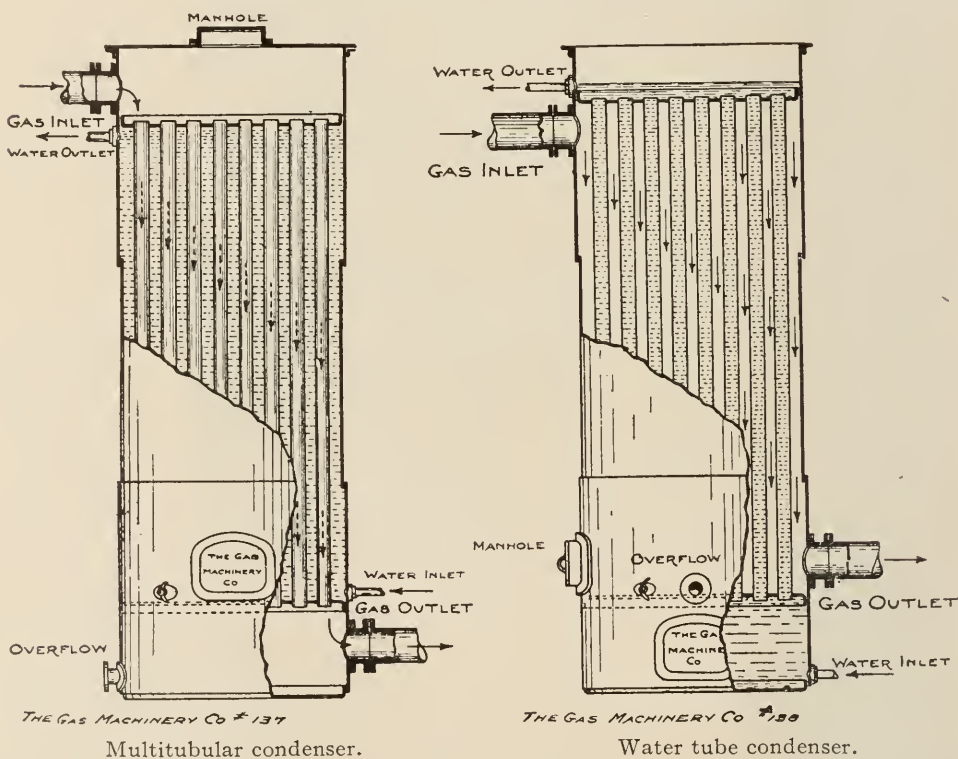
per cent. of the total ammonia. As might be expected, the heavier tars containing a high percentage of free carbon are deposited first together with ammoniacal liquor in which the fixed salts of ammonia predominate, the more volatile salts, such as carbonate and sulphide, being driven forward with the gas.

On the following table is shown an analysis made in the author's laboratory of hydraulic main ammoniacal liquor compared with an analysis of an average sample of the total liquor produced.

Figures represent grains per United States gallon	Well	Hydraulic main
Total NH_3 found by direct distillation.....	1446	362
Total NH_3 as calculated from the sum of component salts.....	1440.3	316.0
NH_3 as monocarbonate.....	1283.0	36.7
NH_3 as monosulphide.....	81.7	6.5
NH_3 as monothiosulphate.....	8.7	46.6
NH_3 as monosulphate.....	4.5	6.4
NH_3 as monochloride.....	32.1	192.4
NH_3 as monosulphocyanide.....	26.8	26.2
NH_3 as monoferrocyanide.....	3.5	1.2
NH_3 as monocyanoide.....	....	....

As the gas leaves the hydraulic main, it still contains from 300 to 350 grains of ammonia per cubic foot together with tarry vapors and other impurities. The next step in its purification is a further cooling to about 105°F . This is accomplished by

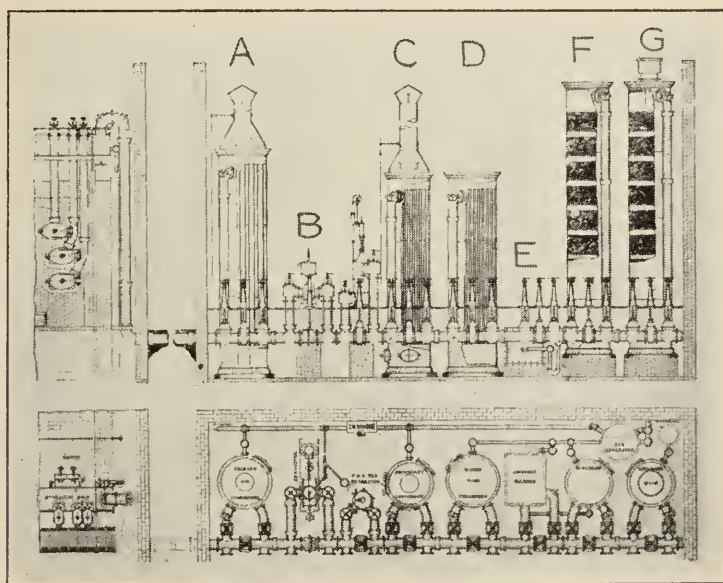
FIG. 5.



means of a primary condenser, usually a cylindrical vessel set vertically and provided with tubes through which the gas or cooling water flows (see Figure 5). Water circulates around the tubes in the multitubular type and through the tubes in the water tube type. In Figure 6 the primary condenser is shown at "A."

The gas having been cooled, passes into the tar extractor which is shown at "B" (Figure 6). In detail this apparatus is shown in Figure 7. Its operation is dependent upon the passage of the gas at high velocity through perforated plates set in such a relation to one another that the gas after passing through the perforation strikes against the surface directly opposite. The passage of the gas through the small perforations agglomerates the tarry mist, its deposition being further assisted by the gas striking upon baffling plates on which the tar is deposited. Provided the temperature is favorable, it is possible to more or less completely remove the tar from coal gas by means of such an

FIG. 6.



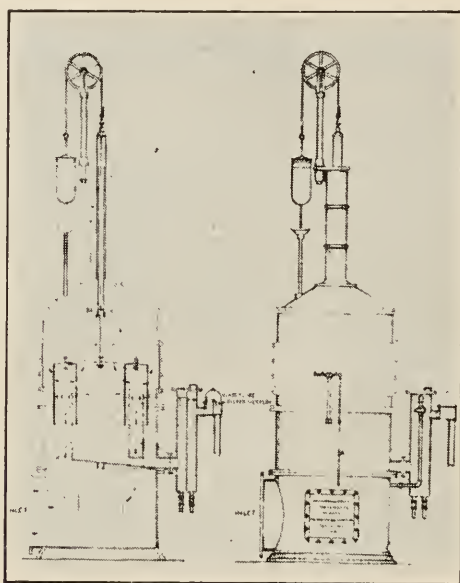
Condensing and scrubbing plant.

extractor and it then remains only to remove the ammonia. This is effected by further cooling of the gas in secondary condensers (see "C" and "D," Figure 6) to about 65° F. and passing it into the tower scrubber "F," in which it is scrubbed with weak ammoniacal liquor, usually that collected from the condensers, hydraulic main, and from the second tower scrubber, which is supplied with fresh water. These scrubbers are filled with grids or coke over which the scrubbing liquor or water flows, presenting a large scrubbing surface to the passing gas. In this manner a liquor is produced containing from 1 to $1\frac{1}{2}$ per cent. of ammonia, depending upon the efficiency of the apparatus and the amount of water supplied.

From the tower scrubbers the gas, now freed from its tar and ammonia, passes to purifiers such as shown on Figure 2, to be freed from hydrogen sulphide. These purifiers are usually large rectangular boxes with removable lids containing shavings coated with oxide of iron. The sulphuretted hydrogen reacts with the iron oxide forming iron sulphide and the gas finally passes into the storage holder commercially pure and ready for distribution, the tar and ammonia liquor being collected in storage wells or tanks provided for the purpose.

A good grade of gas coal will produce, in horizontal retorts, from 12 to 14 gallons of tar per net ton of coal carbonized and

FIG. 7.



P. & A. tar extractor.

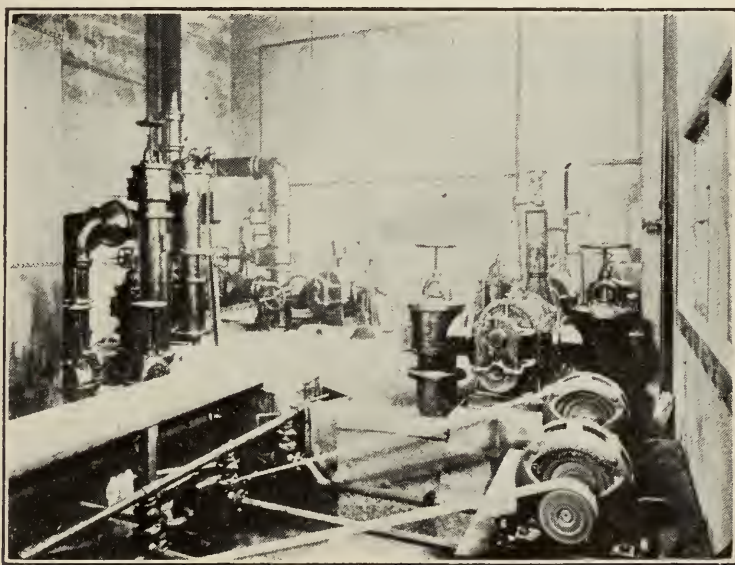
from $4\frac{1}{2}$ to $5\frac{1}{2}$ pounds of ammonia. This amount of ammonia contained in a 1.5 per cent. liquor requires the approximate production of from 36 to 44 gallons of weak liquor per net ton of coal carbonized. A portion of this liquor is derived from the solution of ammonia evolved, in the moisture originally present in the coal and in the water of formation, the balance of the water is supplied extraneously for the purpose of completely removing the ammonia from the gas.

The following example shows the amount of water from various sources per net ton of coal, based on a 1.5 per cent. liquor and a 5-pound ammonia yield:

Moisture from coal.....	2.0	per cent. =	40.0 pounds =	4.8 gallons
Water of formation.....	5.5	per cent. =	110.0 pounds =	13.2 gallons
Fresh water added.....	9.6	per cent. =	192.0 pounds =	23.1 gallons
Total water from all sources.....	17.1	per cent. =	342.0 pounds =	41.1 gallons
Less water carried away in gas at temperature of station meter.....	.46	per cent. =	9.2 pounds =	1.2 gallons
Total liquor.....	16.64	per cent. =	332.8 pounds =	39.9 gallons

The foregoing description covers briefly the recovery of tar and ammoniacal liquor by means of standard apparatus, the simplicity of which has stood the test of time. As might be expected, however, special forms of scrubbers and condensers have been designed with the idea of securing higher efficiencies and reducing the number of separate pieces of apparatus required.

FIG. 8.



Washer cooler showing motor-driven circulating pumps.

Perhaps the most radical departure from the older methods of condensing and scrubbing gas is exemplified in the so-called washer cooler. In this apparatus the laws governing the cooling of gas and the transfer of heat were fully taken into account and a successful attempt was made to obtain a much higher efficiency from the cooling water than was possible in the old style condensers.

This was accomplished by spraying the cooling water directly into the gas without the interposition of a metal diaphragm such as is represented by the condenser tubes. The water after going through the scrubber is brought back to its original temperature

by passing it through a cooler or surface condenser over which small streams of water trickle.

In this method of procedure heat is transferred direct from the gas to the water without having to pass through the walls of condensing tubes, and from water to water. While the transferal in the second step is through an interposing diaphragm, this is not serious when transferring from water to water, although the efficiency is very much lower when transferring heat in this manner from gas to water.

FIG. 9.



Washer cooler showing overhead liquor delivery pipes.

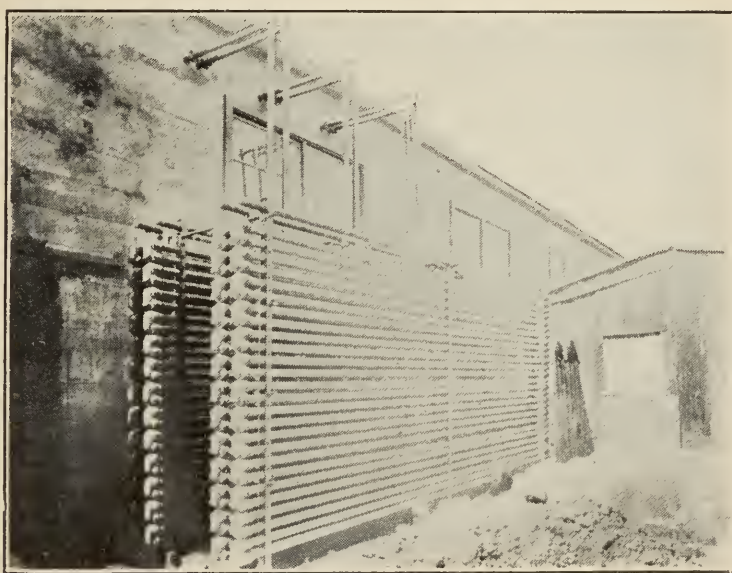
The apparatus is built either circular or rectangular in shape. In the latter case it is divided into 6 or 8 compartments. Each compartment is connected with a rotary pump which carries the water from the bottom of the compartment through cooling coils placed usually outside of the apparatus and sprays it into the top.

In Figure 8 is seen the motor driving the circulating pumps; in Figure 9 the scrubber in position with overhead pipes discharging into the top of the scrubber, and in Figure 10 are shown the cooling coils placed outside the building.

The bottoms of the compartments are connected in such a manner that the liquor or water can flow successively through all of the compartments and out at the gas inlet, and by introducing a small stream of fresh water at the outlet compartment, the apparatus can be made to act also as a very efficient ammonia scrubber.

In Figure 11 is shown a multiple ammonia washer. This apparatus is intended to be operated before the ammonia scrubber. Its purpose is the preliminary treatment of the gas with the liquor from the tower or rotary scrubber for removal of ammonia and mechanically suspended matter. It is claimed that the large

FIG. 10.



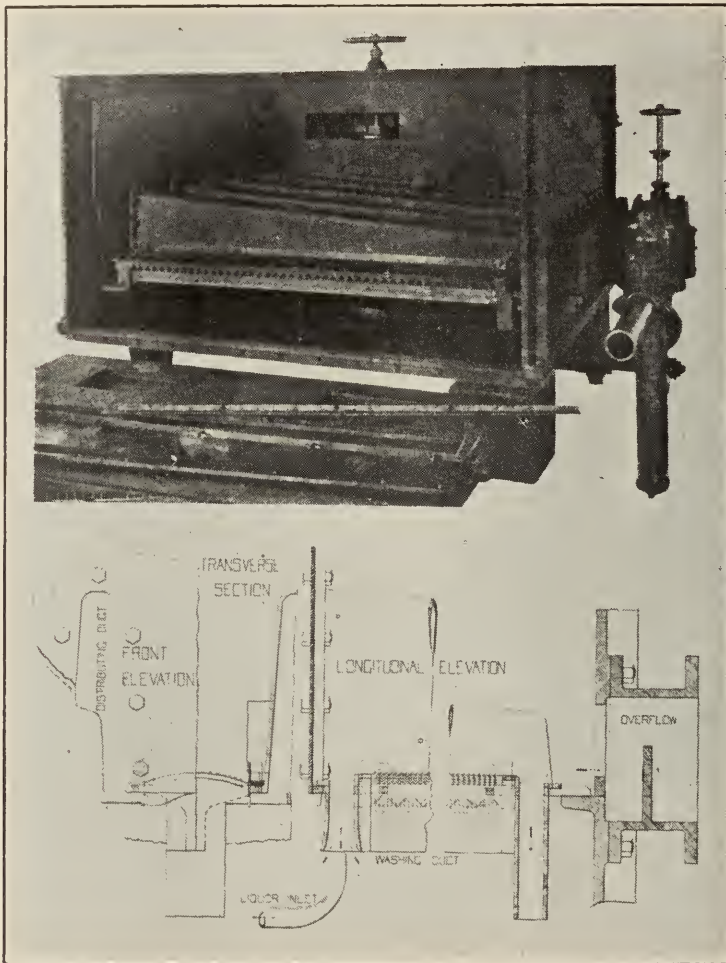
Washer cooler showing cooling coils.

percentage of ammonia here absorbed materially increases the strength of the liquor, while the coincident removal of carbon dioxide and sulphuretted hydrogen increases proportionally the efficiency and capacity of the scrubbers and purifiers. The washer also carries part of the load when it is necessary to temporarily by-pass the tar extractor for repairs in the works.

The washer here described consists of a rectangular box containing a number of cast-iron distributing ducts closed at the back. The open end is bolted to a steel apron forming the inlet chamber of the washer into which the gas enters and passes into the ducts through their open ends and then under the serrated edges of the washing ducts located between the distributing ducts.

The gas in reaching the outlet compartment is subdivided by the serrated submerged edges of the distributing ducts, under which it must first pass, when a second division takes place in its passage through the perforated sides of the washing ducts, and finally through the perforations of the crown sheet, which is covered by the washing liquor in a high state of ebullition.

FIG. 11.



Multiple ammonia washer.

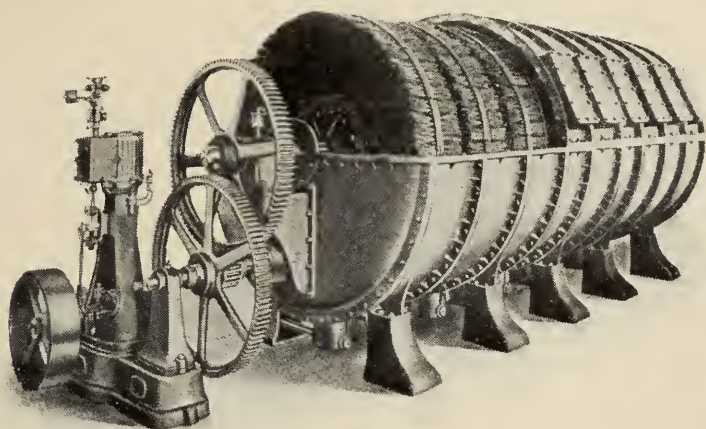
While primarily this apparatus is not intended in any sense to replace the tar extractor, it undoubtedly removes a considerable quantity of tar and at times proves very useful in preventing tar from being carried forward into and fouling the ammonia washer.

Figure 12 shows a mechanical or rotary ammonia scrubber, designed to secure more intimate contact between the ammonia

compounds in the gas and the absorbent than is possible in the tower type. Its action is based on the principle that the ideal scrubber is one in which the greatest wetted surface is obtained in the smallest gross volume. Some mechanical scrubbers are provided with wooden grids, others with iron plates, and still others with fibre brushes. The scrubber shown is of this last construction.

The brushes are fastened to a shaft which is made to revolve, and as the scrubber is about one-third filled with water, the brushes continually rising from the water present freshly wetted fibres to the passing gas. The wetted surface presented is very large, and it is possible with this scrubber to obtain a liquor con-

FIG. 12.



Rotary scrubber.

taining over 5 per cent. of ammonia, at the same time reducing the ammonia content of the gas to less than three grains per 100 cubic feet.

It is claimed that scrubbers so equipped have successfully handled over 2000 cubic feet of gas per day per cubic foot of gross volume, this being rendered possible by the brush construction, which gives 42 square feet of wetted surface per cubic foot of gas passed per minute and 91 square feet of wetted surface per cubic foot of actual gas passageway; in other words, over 30 square feet of wetted surface per 1000 cubic feet of gas passed per day. The enormously increased capacity is appreciated when it is considered that ordinary tower scrubbers require 15 cubic feet gross volume per 1000 cubic feet of gas per day.

Through the courtesy of the builders of this apparatus, I

am able to give a working test, which shows a very high efficiency in respect to ammonia removed, and also that a very considerable amount of carbon dioxide and sulphuretted hydrogen were removed at the same time:

Ammonia (NH_3) in gas at inlet.....	45.10 grains per 100 cu. ft.
Ammonia (NH_3) in gas at outlet.....	.13 grains per 100 cu. ft.
Ammonia (NH_3) in gas removed.....	99.7 per cent.
Carbonic acid (CO_2) in gas at inlet.....	4.6 per cent. by volume
Carbonic acid (CO_2) in gas at outlet.....	4.0 per cent. by volume
Carbonic acid (CO_2) removed.....	13.0 per cent.
Sulphuretted hydrogen (H_2S) in gas at inlet.....	2.2 per cent. by volume
Sulphuretted hydrogen (H_2S) in gas at outlet.....	.8 per cent. by volume
Sulphuretted hydrogen (H_2S) removed.....	63.6 per cent.
Rated capacity of rotary scrubber.....	3,500,000 cu. ft. per diem
Gas treated by rotary scrubber.....	4,090,000 cu. ft. per diem
Overload 17 per cent. 56/100 gallon water used per	1000 cu. ft.

Figure 13 shows a plant layout with tower scrubbers replaced by a multiple washer and rotary scrubber.

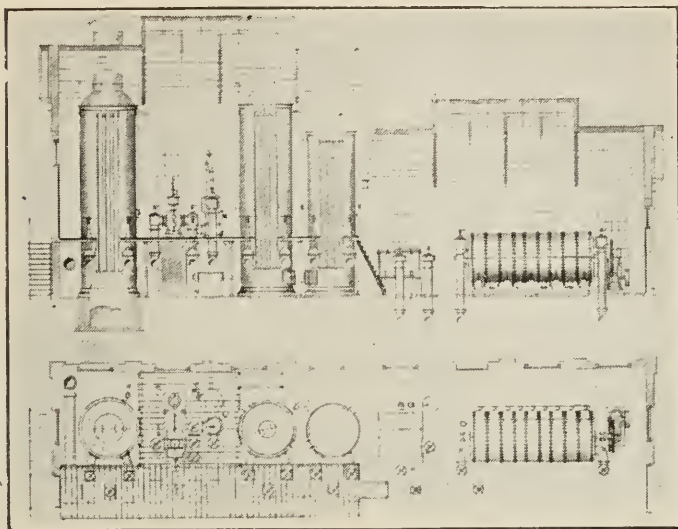
A scrubber that is considered by many as a distinct advance over the tower or rotary type, is the so-called Intensive Scrubber shown on Figure 14. This scrubber is divided into compartments resembling somewhat a number of tower scrubbers in series, the gas passing up through the grids while the washing liquor flows down over and through the same grids and in intimate contact with the gas.

Figure 15 shows the scrubber with some of the plates removed showing the grids in place. A steam engine or motor drives the countershaft operating the pumps which carry the washing liquor to the tops of the various compartments (see Figure 16).

At the base of the scrubber are decanting chambers, one for each of the compartments. These are kept full of liquor to the top of the weirs, by fresh water supplied into the last chamber. The liquor flows in succession into and through all of the chambers and passes out of the apparatus at the liquor overflow on the first or inlet gas compartment. The liquor in the various compartments is kept separated by the weirs above referred to. The tops of these weirs are at a gradually descending height from outlet to inlet; the liquor in the adjoining compartments is thus prevented from mixing. The liquor in the decanting chamber of each compartment is handled by its own pump, which carries it continuously to the top of the chamber, where it is distributed over the grids.

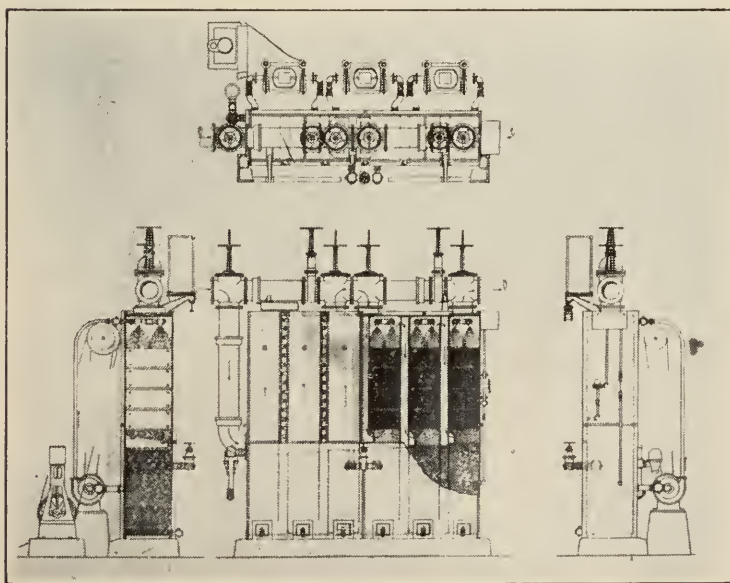
The gas enters the first compartment, and rising through the scrubbing plates therein meets the descending liquor, which is sprayed into the top of the compartment. The gas then passes

FIG. 13.



Coal gas condensing and scrubbing system with rotary scrubbers.

FIG. 14.



Intensive scrubber

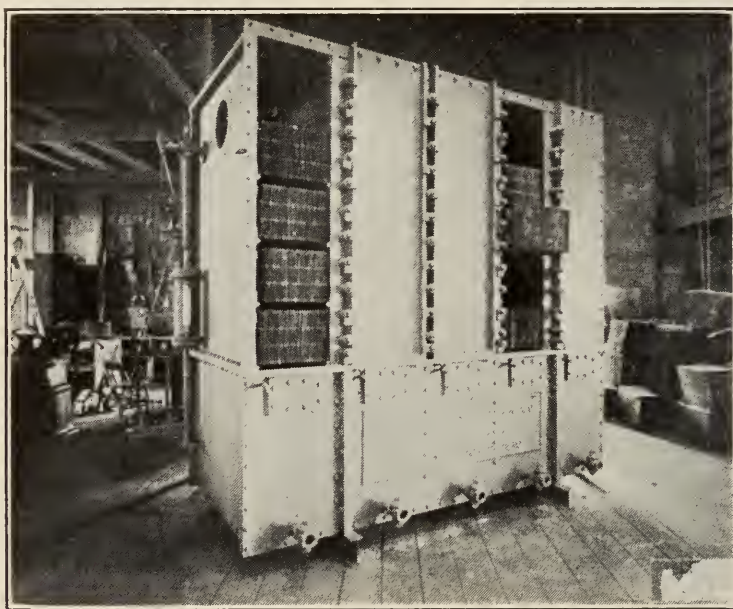
down through the conduit formed by the division walls, enters the bottom of the second compartment, rising through the grids, and descending to the third compartment, and so on to the outlet ;

in each successive step losing a portion of its ammonia as it meets the weaker liquor flowing in the reversed direction.

The construction of the apparatus and the operation of the sprays insures a thorough wetting of the very large surface exposed, permitting operation at high efficiency.

The advantages claimed for the Intensive Scrubber over tower scrubbers are—much less space occupied and the possibility of producing a high strength liquor with a very small quantity of water. As compared with rotary scrubbers, the makers claim a number of advantages in addition to the fact that the scrubber occupies less space. All of the scrubbing surface is continually

FIG. 15.



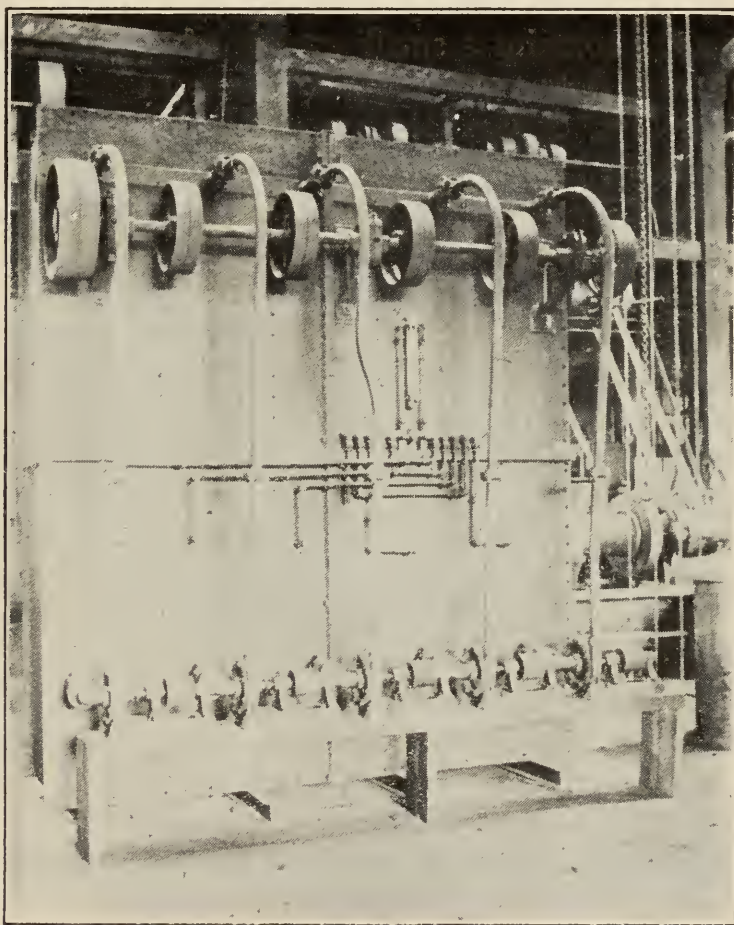
Intensive scrubber (with grids exposed).

in use, which is not true of rotary scrubbers, wherein a portion of the grids or brushes are at all times submerged.

The constant efficiency of all of the scrubbing surface is also one of the claimed advantages. It is pointed out that in the Intensive Scrubber, the liquor on any given area of scrubbing surface is always at the same degree of saturation of ammonia, and hence, has a constant absorptive power. But in all rotaries, the scrubbing surface is rotating while the gas is passing through the scrubbing drum radially. Hence there is a continual decrease in absorptive power of the liquor adhering to the emerged grids in each revolution, as the rotation proceeds, until towards the end

of it, the adhering liquor has come into equilibrium or equal vapor tension with the gas and some gas will, therefore, pass through without leaving any ammonia in that section. The portion of the free revolution during which it will absorb ammonia, is a variable, determined by the speed of rotation and the quantity of gas passing. In the Intensive Scrubber, on the

FIG. 16.



Intensive scrubber. (Showing motor-driven circulating pumps.)

contrary, there is a continual application of the contracurrent principle, whereby foul gas is always meeting cleaner liquor.

Another feature upon which considerable emphasis is laid is, that owing to the large amount of scrubbing liquor continually passing through the grids, they are very little unlikely to become fouled with naphthalene or tar, the heavier tar being carried to the bottom of the compartment, below the level from which clean liquor is drawn.

This apparatus is often worked in combination with the washer cooler, and together they constitute a condensing and scrubbing system entirely different from the old style apparatus, and the best evidence of the practicability and efficiency of the system is the steadily increasing number of installations throughout the country.

Irrespective of the type of apparatus employed, the tar and ammoniacal liquor are finally collected into separate wells or tanks. The tar contains a small amount of ammoniacal liquor, usually not over 6 or 7 per cent. The ammoniacal liquor contains 1.5 per cent. or over total ammonia, in which state it is ready for further concentration. The tar is usually sold to tar distillers without further refinement, but in order to reduce transportation charges, the ammoniacal liquor is concentrated until it contains from 15 to 20 per cent. of ammonia.

Before entering upon a description of the apparatus employed for concentration, mention should be made of a direct system of ammonia recovery which, although it has not been extensively employed in gas plants, has proven entirely practicable and highly efficient in coke oven practice. There appears to be no good reason why it should not be well adapted to the conditions found even in a modern sized gas works, and experience abroad, where it has been tried, has justified the above conclusions.

The general layout of the plant is shown on Figure 17. The gas from the ovens passes first to a series of condensers of the multitubular type, which reduces the temperature to a point where the tar can be completely removed by a P. & A. condenser. The gas then passes to a reheater, where it is brought to about 160° F. From thence it goes to a saturator containing sulphuric acid, where the ammonia is absorbed, forming ammonium sulphate. The condensates from the primary condensers and the tar extractor are conducted to an ammonia still, where they are treated with lime for the purposes of recovering the fixed ammonia, the vapors from the still being passed into the gas main and a complete conversion of the ammonia in the gas into sulphate is thus accomplished. This system entirely eliminates the necessity for ammonia washers and concentrators, and possesses other decided advantages.

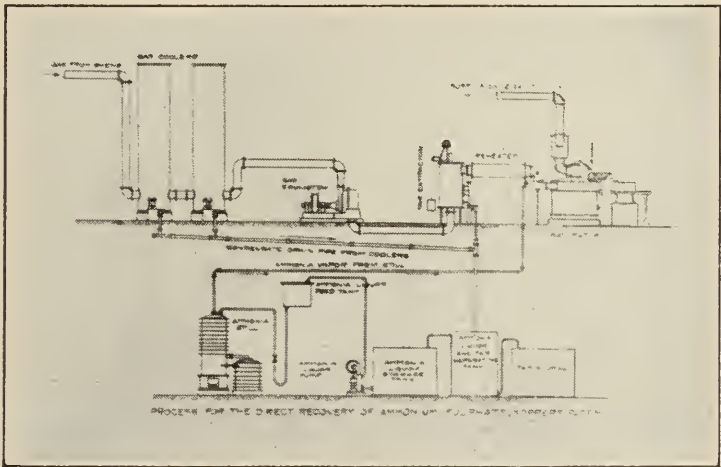
In a somewhat similar system, the tar is removed at high temperature by scrubbing the gas with a tar spray which removes all of the tar but very little of the ammonia. The gas

then carrying practically the full content of its ammonia passes into a saturator and is converted into sulphate as in the first process.

As before stated, it is the general practice in this country to merely concentrate the weak liquor obtained in the ordinary process of condensing and scrubbing the gas in order to save the freight on excess water.

Two prominent types of stills are employed: one known as the *continuous type* and the other as the *continuous feed-intermittent effluent type*. In the first form the liquor is fed into the still continuously and the waste passes from the still continuously. In the second form, the liquor is fed into the still continuously,

FIG. 17.



Process for the direct recovery of ammonium sulphate.

but the waste is drawn off intermittently. On Figure 18 is shown a well-known example of a continuous still.

The apparatus illustrated shows a still of medium size, but the internal arrangement is the same in all, from twenty-four inches to eighty-four inches in diameter. The eighteen-inch machine operates on the same principle, and differs only in that there are somewhat fewer parts.

For a proper understanding of the action of the still, it may be well to trace the flow of liquor from the well through the apparatus. A pump lifts the liquor to an overhead feed tank, from which it passes to the heater, where it is preheated by the vapors rising through cast-iron pipes fitted into the diaphragm, which separates this unit from the first section of the still.

The liquor overflows into the central one of these tubes,

which is somewhat shorter than the others, and passes into the top chamber of the volatile still, which consists, as shown by the illustration, of a series of chambers provided with baffles and overflows. The liquor, in descending from chamber to chamber, is brought into intimate contact with the hot, rising vapors and reaches the lower section freed of its volatile ammonia. The liquor then passes through the dip pipe down into the lime leg,

FIG. 18.

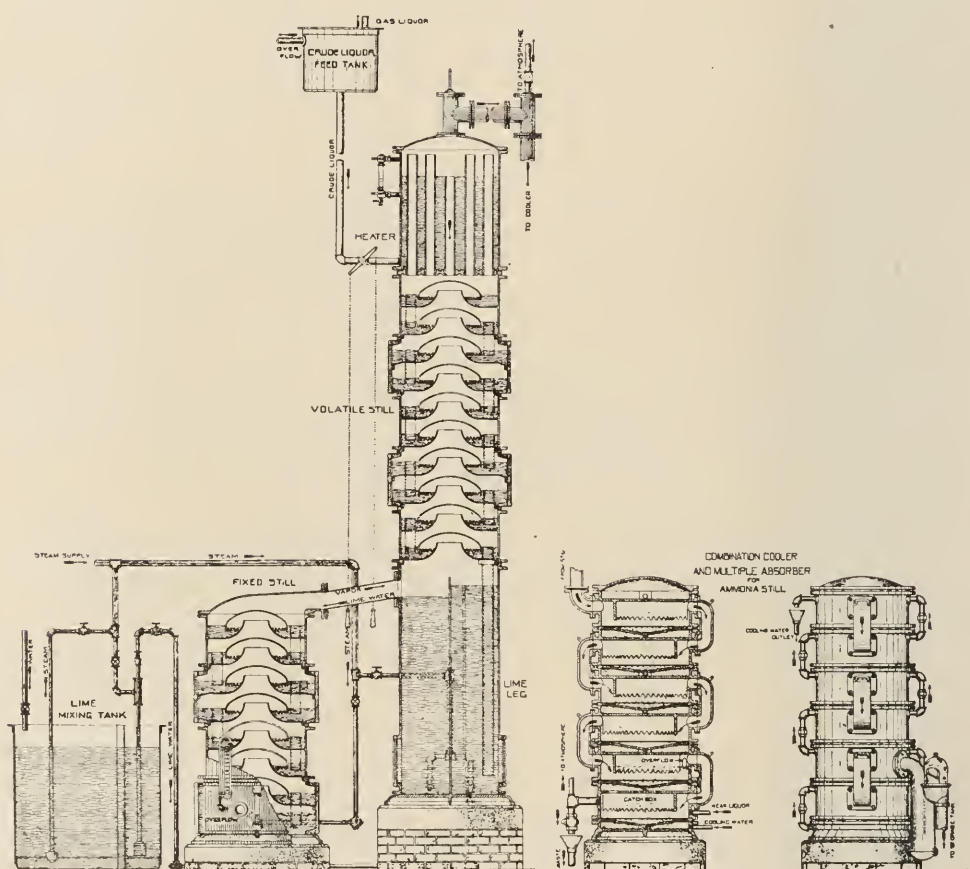


Fig. 4.

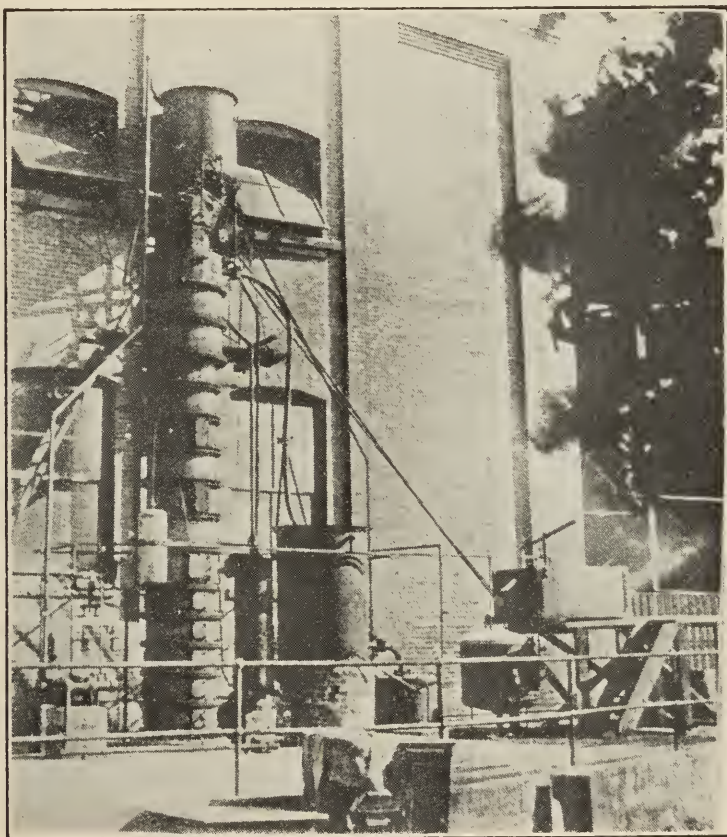
Continuous type of ammonia concentrator.

where it is brought in contact with the lime just as it enters at the bottom of the still. The arrangement shows the manner in which the combined liquor and the milk of lime are made to traverse the entire length of the lime leg twice before overflowing to the fixed still, thereby insuring extended and intimate contact between the lime and the fixed salts. Steam inlets are provided in the base of the lime leg on each side of the vertical

diaphragm, both for the purpose of increasing the temperature at this point as well as for stirring up the lime mixture.

The liquor and lime water finally overflow into the top section of the fixed still and down through a series of chambers identical in construction with those of the volatile still. When the bottom section is reached, the waste liquor passes to the sewer and contains only a very small amount of ammonia, usually not over 0.005 or 0.01 per cent.

FIG. 19.



Continuous ammonia concentrator.

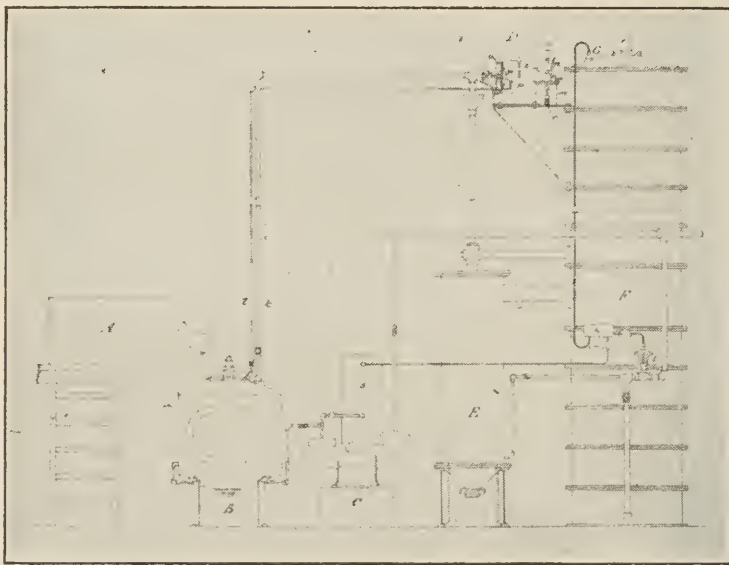
Figure 19 shows another prominent type of continuous still. Its general plan of operation is similar to the type above described. In detail, this apparatus is shown on Figure 20.

The still illustrated has six sections in the volatile still, with partitions between them and partitions cast in, so there are eleven compartments, and six sections, each of one compartment, in the fixed still. The liquor enters at top in a steady stream, descends through the three compartments of the washer and is deflected

into an outside pipe leading into the bottom of the heater, in which it is heated to about 190° F., and overflows near the top of the heater into an outside pipe leading to the tenth compartment of the volatile still. The liquor in the heater surrounds a number of lead pipes in which circulate the hot vapors coming from the still, the condensate in the pipes returns to the still and the cooled vapors pass through the side of the heater into a tee, containing a thermometer and a thermostat, for regulating the steam supply, and then into the lead pipe coil of the condenser.

The bottom end of the lead pipe protrudes through the side of the condenser and is bent downwards in the shape of a goose-

FIG. 20.



Continuous ammonia concentrator showing construction detail.

neck into the centre of the absorber, and extends half-way into the concentrated liquor. The concentrated liquor overflows into the pipe leading to the storage tank through a seal made of cast iron flanged fittings, in which there is an overflow casting containing a bell-glass.

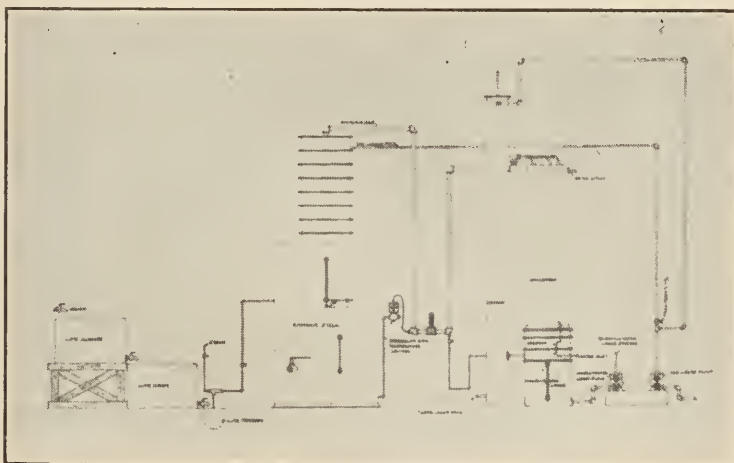
The automatic valve for feeding the milk of lime is placed on a support between the heater and condenser, above the funnel and on top of the pipe coming from the lime leg, and discharges about half a gallon of milk of lime at time intervals, depending upon the amount of milk of lime required. The mixture of hot liquor and lime overflows from the lime leg into the top of the fixed still, in

which it is subjected to heavy boiling through deep seals and gradually freed from the ammonia, so there need not be more than 0.005 per cent. ammonia in the waste escaping from the bottom compartment.

Figures 21 and 22 are two views of a still of the continuous feed-intermittent effluent type. In this still the liquor is fed continuously but the effluent is drawn off usually at two-hour intervals.

By referring to Figure 22 the operation of the still will be understood. A dephlegmating column similar to those previously described is placed on the top of a cylindrical tank set vertically. This tank is divided into two compartments having hopper bot-

FIG. 21.



Continuous feed-intermittent effluent concentrator.

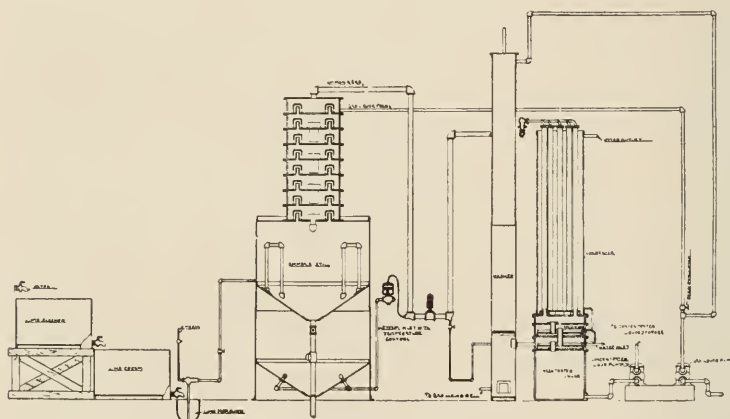
toms, the compartments being connected through an opening in the apex of the cone. This opening is controlled by a cock which can be operated from the outside of the still, and permits of the passage, at will, of the liquor from the top compartment to the bottom compartment. Steam inlets are provided, as shown, in the bottom compartment. The top of the column is connected through a goose-neck with tubular condenser and receiver and means are provided for introducing milk of lime. The operation of the still is as follows:

The liquor is fed into the top of the column, flows down through overflows sealed in liquor until it finally discharges into the top section of the still. In its descent it meets the ascending steam charged with ammonia vapor. The capacity of the still is

such that the top compartment will be filled about two-thirds in two hours. The cock connecting the two compartments is then opened and its content dropped into the bottom compartment, milk of lime having been added to the liquor before it is dropped to the bottom compartment. Just before again dropping the contents of the top compartment, the lower compartment is discharged into the sewer, practically all of the ammonia, both fixed and volatile, having been driven from the liquor.

The still is exceedingly simple to operate, and, in the opinion of many, possesses decided advantages over the continuous effluent type. Chief among these is the perfect control over the character of the waste, in respect to ammonia content, obtained by the intermittent discharge.

FIG. 22.



Continuous feed-intermittent effluent concentrator, showing vertical section.

In conclusion, brief mention should be made of another gas works by-product, cyanogen, which, although extensively recovered abroad, has received, up to the past few years, but little attention in this country. Recently, however, one large gas company has installed apparatus for cyanide recovery, and good results are reported.

Cyanogen occurs in coal gas as free cyanogen $(CN)_2$ and hydrocyanic acid (HCN) , both of which are gases. It is formed by the combination of a small percentage of nitrogen contained in the coal, with the necessary amount of carbon. The amount occurring in the gas is dependent upon the temperature of distillation, high heats being conducive to a high cyanogen yield. A temperature of about $1735^{\circ} F.$ is said to be most favorable.

The yield of hydrocyanic acid will then be between two

and three ounces per thousand feet of gas. It is rare in this country that as much as three ounces are produced, owing to the comparatively low heats carried. Several tests made in an American gas works showed something over two ounces; being higher at one station than at another in the same works, due, presumably, to slightly different heats carried.

At works where no attempt is made to remove the cyanogen from the gas, about 10 or 15 per cent. is taken out in the ammonia scrubbers, and the rest more or less completely removed in the purifiers, occurring there as Prussian blue. Up to a few years ago, the spent purifying material was the chief source of cyanides, but it was soon recognized that only a portion of the whole could be recovered in this way, and attention was given to its recovery from the gas itself.

Numerous processes have been devised for wet scrubbing, the earliest being the Knublauch System, which system consisted in bringing the gas, by means of a mechanical scrubber, into intimate contact with a solution containing an alkali and the salt of a heavy metal, preferably iron. In this way, soluble ferrocyanides are formed and recovered from the wash liquor by evaporation and crystallization.

There were several defects in the Knublauch system and at present it has given way to other systems which are more efficient and more easily controlled. All of these, however, except perhaps the process exploited by the British Cyanide Company are based upon the Knublauch principle. A brief outline of the most important systems in use to-day is as follows:

Feld Process.

In the Feld system, the cyanide washed is placed immediately after the ammonia scrubber, operating on gas freed from ammonia. The washer employed is usually of the standard rotary or bubbling type. Solutions of lime and ferrous sulphate are used as the scrubbing material, being introduced separately and continuously into the washer. The product obtained is a solution of calcium ferrocyanide, from which the pure salt can be crystallized.

Stavorinus Process.

In the Stavorinus process the washer is placed immediately after the tar extractor and operates therefore on gas *containing* ammonia. The scrubbing material employed is a solution of po-

tassium carbonate, and iron carbonate made from ferrous sulphate in suspension. The product obtained is a soluble alkaline ferrocyanide. Although the system is arranged for a continuous flow, the process is really intermittent.

Two or three times a day a quantity of saturated liquor is drawn from the last bay of the scrubber and fresh liquor poured in. Since a large amount of ammonia is dissolved with the soluble cyanide, it must be recovered by boiling off in some form of concentrator. The residual sludge is then pumped into a filter, where it is converted into a clear solution and a cake, the solution consisting of potassium ferrocyanide, potassium sulphide, and potash. This liquor is evaporated until it throws down the salt.

British Cyanide Process.

In this process the gas is treated, immediately after the tar extractor, as in the Stavorinus process. A mechanical scrubber is employed having nine bays. Over eight of these bays is fixed a conical cup for holding the sulphur. Ammoniacal liquor is pumped into the washer at the outlet end, and granular sulphur is introduced intermittently into the eight bays. Ammonium sulphocyanide is formed and is disposed of as such.

Bueb Process.

In the Bueb process the cyanide washer is placed after the tar extractor. This process also operates on gas containing ammonia. A ferrous sulphate solution is employed as the scrubbing material. The product produced is a mixture of insoluble cyanides, which is sold in its crude state.

Another by-product of less importance, but having some commercial value, is the sulphur which separates out in the revivification of spent oxide. This accompanies, however, in coal gas practice, a considerable quantity of cyanogen and the value of the oxide when sold is usually based on its cyanogen content rather than on the sulphur, though the latter may be used for the manufacture of sulphuric acid.

While in the foregoing paper chief consideration has been given to tar and ammoniacal liquor, the fact should not be lost sight of that the coke produced is in reality the most valuable of all of the by-products. In ordinary gas works practice, after deducting that necessary for heating the furnaces, there will be left for sale an amount equal to about fifty per cent. of the coal

carbonized. Analysis of a typical gas house coke is about as follows:

Moisture .....	.16 per cent.
Volatile combustible	1.46 per cent.
Fixed carbon	88.80 per cent.
Ash	9.58 per cent.
B. T. U's per pound	12,240

It is extensively used for domestic and furnace purposes, and usually finds a ready sale at from \$3.00 to \$5.00 per ton, representing, as it does, a clean smokeless fuel at moderate cost and high heating value.

I have endeavored in the foregoing paper to describe the general methods of procedure in a modern gas works, in the recovery and preparation for market of the most important by-products, and also to give a brief description of apparatus, representing the most approved practice at the present time.

A great deal has been written on the general subject of gas manufacture and much also bearing upon the industry of tar and ammonia distillation. It was not hoped or intended, therefore, that this paper would "fill a long felt want," but merely that it would throw some additional light on a phase of the gas business which has usually been considered from another angle and subordinate to the principal object.

Within the last few years, however, rapidly changing conditions have caused considerably more attention to be given to the economical and complete recovery of these substances and it is perhaps not an unsafe prediction to make,—in these days of rate regulation and high cost of raw material,—that these by-products of the gas industry, now steadily increasing in importance and value, will become the hope and stay of the business, and that the field of their recovery and exploitation will be a fruitful one for the exercise of the inventive skill and business acumen of the gas engineers and chemists of to-morrow.

The author wishes to express his indebtedness to Mr. George H. Cushing, editor of *The Black Diamond*, for permission to reproduce Figure 1; to The Western Gas and Construction Company, The Gas Machinery Company, The Improved Equipment Company, The Isbell-Porter Company, The Lloyd Construction Company, The Koppers Company, The American Gas Institute, and to Mr. W. L. Rowland for other illustrative material.

Refractory Materials for Gas Retorts. F. J. BYWATER. (*J. Gas Lighting*, cxxvi, 899.)—*Silica Retorts.*—These have been used recently in America with satisfactory results. The retorts were made from crushed ganister quartz (95 per cent. SiO_2), with 2 per cent. milk of lime as the binding medium. They were of D-section, and were built up from bricks and tiles. The expansion on heating was from $\frac{1}{8}$ to $\frac{3}{16}$ inch per foot, and was allowed for by making the joints either with thick paper or straw-board, which burned away, leaving a thin carbon joint, or with cement consisting of mild aluminous clay, which shrank when heated. The mouthpiece ends of the retorts were made of solid moulded fireclay so as not to crack when cooled by the opening of the lid. The retorts were used with various types of hydraulic discharging machines. In some cases less carbon was formed on the inside of the silica retorts and the surface became glazed, facilitating discharge by pushers. The life of the retorts was $3\frac{1}{2}$ to 4 years. The thermal conductivity was greater than with clay retorts, the fuel consumption was less, and the output greater, owing to the shorter period required for burning off the charge.

Testing Refractory Materials under Load.—The melting-point of various clays used in the manufacture of firebrick and retort material was found to be 200° to 320° C. lower when the clay was under pressures of 54 to 112 pounds per square inch.

Flameless Incandescent Surface Combustion. H. H. GRAY. (*J. Gas Lighting*, cxxvi, 786.)—The author criticises the view that surface combustion consists in a catalytic action of the incandescent surface and that the combustion takes place in molecular layers in contact with the surface. The size of a gas flame is reduced by increased aëration, and depends upon the time required for the gas and the oxygen to mix and burn. The absence of flame when a mixture of gas and air is brought into contact with an incandescent surface is, therefore, to be expected. The process occurring in the tube of a Bonecourt boiler is considered to be a modified detonation in which the propagation of the combustion through the gaseous mixture is effected by the incandescent solid instead of by the adiabatic compression of a detonation wave. The setting up of a detonation wave is prevented by the rapid flow of gases in the opposite direction and by the baffling effect of the solid material.

Action of Weak Acids on Soluble Fluorides. P. A. E. RICHARDS. (*Analyst*, xxxix, 248.)—Lactic, butyric, tartaric, malic, citric, formic, salicylic, and benzoic acids all liberate hydrofluoric acid from potassium and sodium fluorides, even with 1 per cent. acid solutions. Carbon dioxide also liberates the hydrofluoric acid from these fluorides, but none of the acids mentioned attacked calcium fluoride.

SEWAGE TREATMENT.*

BY

RUDOLPH HERING, D.Sc., C.E.,

Member of the Institute.

CHAIRMAN AND GENTLEMEN: The subject on which I was asked to speak to you to-night is the treatment of sewage. Since the introduction of water supplies into cities this subject has become an important one in many cities. The water as it passes through the city receives the dirt, dust, and excremental discharges from our houses and, together with rain-water, also the dirt and dust that has accumulated upon the streets, roofs, etc. We have turned the clean water furnished us into dirty water, then called sewage, which is discharged into sewers and reaches the nearest watercourses and, with them, finally the ocean.

As cities grew and the watercourses were small their water frequently became offensive. The heavier matters were deposited in the streams as sludge and putrefied, while the flowing water was deprived of its dissolved oxygen, and both sludge and water became offensive.

It was later found that diseases were caused by certain bacteria which were discharged from our bodies while sick, and entered the sewers and the streams. Sometimes these germs became free and infected the air, or the polluted water was used in such ways that the germs entered human bodies and made them sick. Gradually, therefore, the sewage question became not only one of convenience of city life but one of health.

The first serious troubles were experienced in England, where the communities are crowded and the rivers are small. England had also been the first country to generally introduce modern water supplies into houses. Many of its rivers soon began to get foul and sometimes dangerous to health. Therefore the subject of sewage collection and disposal received most attention and the first satisfactory solutions in England.

To-day we have reached the conclusion in all civilized countries that it is practicable and economical to collect sewage

* Presented at the meeting of the Mechanical and Engineering Section, held January 15, 1914.

from houses and cities, and to carry it away underground in sewers, to be delivered either into flowing streams or onto land in such ways that it will neither become a nuisance nor be of any injury to health.

We can now design the house sewers or drains and the receptacles of the waste water in such a way that by cleanliness and proper ventilation we need not have a nuisance in the house nor give disease germs in the sewage an opportunity to enter the same.

We can now design the city sewers in a way so that they can carry the sewage or dirty water from the houses to the out-

FIG. 1.



Poorly-drained land bordering stream in Emscher district of Germany.

falls without causing any nuisance or danger to health on the streets.

There are many cities, particularly in Europe, where there is no offensive odor within the sewers. In Paris, Hamburg, Wiesbaden, and other cities even visitors regularly inspect them who desire the sensation of passing through these waste-water channels under the streets. I feel satisfied that it is only a question of time when in all cities we shall have our sewerage systems so built and maintained that no more offence will arise from them than we now expect in our bathrooms, water-closets, or kitchens.

When the sewage from the house gets into the sewer it consists of liquids and solids. At first nearly all of the matter which is liable to become offensive is in solid form. The sewage can

be strained when leaving a house, and the liquid on standing will rarely, if ever, become foul, because whatever little dissolved organic matter it may contain is oxidized by the large quantities of dissolved oxygen. As the sewage runs on the solid matter is more and more dissolved. After a mile or two, and generally at the outfalls, we find that about one-half of the waste organic matter is in solution. After flowing many miles a still larger part is dissolved.

It is important to realize this last fact, because the question of sewage disposal and treatment is very much dependent upon

FIG. 2.



Land bordering stream in Emscher district of Germany after improvement of stream channel.

the physical condition of the sewage and whether there is much organic matter in solution or not.

The nuisance resulting from sewage is caused by the gradual exhaustion by this matter of the oxygen dissolved in the water. Organic matter as it decomposes first consumes oxygen, and when the latter is all gone an entire change takes place in the process, and hydrogen is then consumed. The first process we call oxidation, and it is entirely inoffensive. The other process we call putrefaction, and it is quite offensive. It is the condition which we have tried to prevent and can now prevent, knowing better than formerly the conditions under which it occurs.

Both oxidation and putrefaction are accomplished by the action of bacteria, which fact, as it concerns sewage, has been

known only for the last thirty or forty years. Since the discovery of bacterial action in converting dead organic into mineral matter we utilize two classes of bacteria for this purpose. One class is that of the aërobic bacteria which cause oxidation in the presence of oxygen; the other class is that of the anaërobic bacteria which live in the absence of oxygen. We are concerned, however, with two orders of anaërobic bacteria. One produces putrefactive or offensive conditions, the other does not. This fact has been applied to sewage treatment only within a few years. The latter kind are not putrefactive; they decompose the

FIG. 3.



Open sewer in Emscher district of Germany.

sewage without oxidation and yet do it in an entirely inoffensive way. Offensiveness is caused by the production of bad-smelling gases, of which the principal one is sulphuretted hydrogen. We can now prevent the development of sulphur bacteria, which produce this gas, by creating conditions which allow other bacteria to develop which produce marsh gas and carbon dioxide, neither of which is offensive. In the modern methods of sewage treatment we therefore endeavor to utilize the aërobic bacteria, and, of the anaërobic bacteria, chiefly those which produce marsh gas and carbon dioxide. This practice constitutes the greatest progress we have made in sewage treatment during the last few years.

We can now say that the entire process of sewage collection

and disposal, from start to finish, can be conducted inoffensively. We do not hesitate, as we did less than fifty years ago, to have a bathroom next to our bed- or living-room. The kitchen sink has less odors than formerly. Street sewers in many cities are no longer offensive.

We have not yet advanced as far as this in all street sewers, particularly in our country, because they are not all properly built nor cleaned. The suspended matter carried by the sewage is frequently retained either by deposit or by the roughness of the sewer lining or by eddies formed, where the flow is not

FIG. 4.



Sewage screen.

regular. In such cases where the retention is more than a day the dissolved oxygen becomes exhausted and putrefaction begins. To prevent this retention the sewage must have a steady and regular flow and rapid velocities, and the interior surface against which the sewage flows must be as smooth as practicable. All the progress in city sewerage that has been made in the last fifty years has been along these lines, so that as a result thereof the sewage not only is devoid of odors in the sewer but is delivered at the outfall with a remnant of dissolved oxygen and without putrefaction. In fairly good sized towns properly sewered and where the sewers are kept clean I have never observed at the outlet anything worse than a stale odor.

To get this result we should also have proper means of flushing the sewers, and also of well ventilating them so that they contain fresh air at all times. The oxygen of the air replenishes what is being exhausted by decomposing matter in the water and by the temporarily stranded matter along the sides. In Europe it is customary to flush the smaller sewers once or twice a week, the larger ones once or twice a month. In our country we do not yet flush the sewers as much as we should, and in most cities the flushing is left to the rain-water which enters occasionally. Rain-water flushing may prevent serious deposits, but it will not pre-

FIG. 5.



Grit chamber during cleaning.

vent temporary deposits which produce the objectionable odors. Small sewers are flushed by automatic flush tanks, which generally keep the smaller sewers in a better condition than the larger ones.

Flushing and ventilating not only prevent nuisance but also help to remove disease germs. Ventilation either tends to desiccate them or to scatter them by dilution to points where they are likely to perish. Flushing carries them away to the out-fall. A large number of pathogenic bacteria connected with typhoid fever and diarrhoeal diseases are doubtless contained in sewers. Yet careful inquiries made in Europe and here have not resulted in the discovery of a single case of typhoid fever or

dysentery which could be directly traced to sewer air where sewers had been kept clean and fresh.

Sewers were first introduced for the purpose of carrying away rain-water. It was only a second thought to carry away also the waste water from the houses through the introduction of the so-called water-carriage system of sewage removal. The method of uniting the sewage and rain-water in the same channel has caused what is known as the combined system of sewerage.

In recent years it has frequently been found more economical to carry the dirty water or sewage away by a separate system of pipes, and the rain-water by another system. An economy results from the fact that in building up town areas we are generally more concerned at first in removing the dirty house water in pipes than the street water, and are willing to let the latter run off on the surface so long as no trouble is caused thereby. When the latter becomes objectionable, then it often happens that much shorter drains are required, because the rain-water is comparatively clean and can be discharged into any near brook, while the sewage must be carried farther away and perhaps must be treated. Sometimes a city has both systems, as, for instance, your own city of Philadelphia, where the combined system is used for the largest part, but where in the suburbs there are sections where the separate system has been preferred as being less expensive.

The separate system is generally preferred where the sewage must be treated in some way, and where it must be pumped. Should there be a large amount of rain-water mixed with the sewage, the treatment and the pumping become expensive.

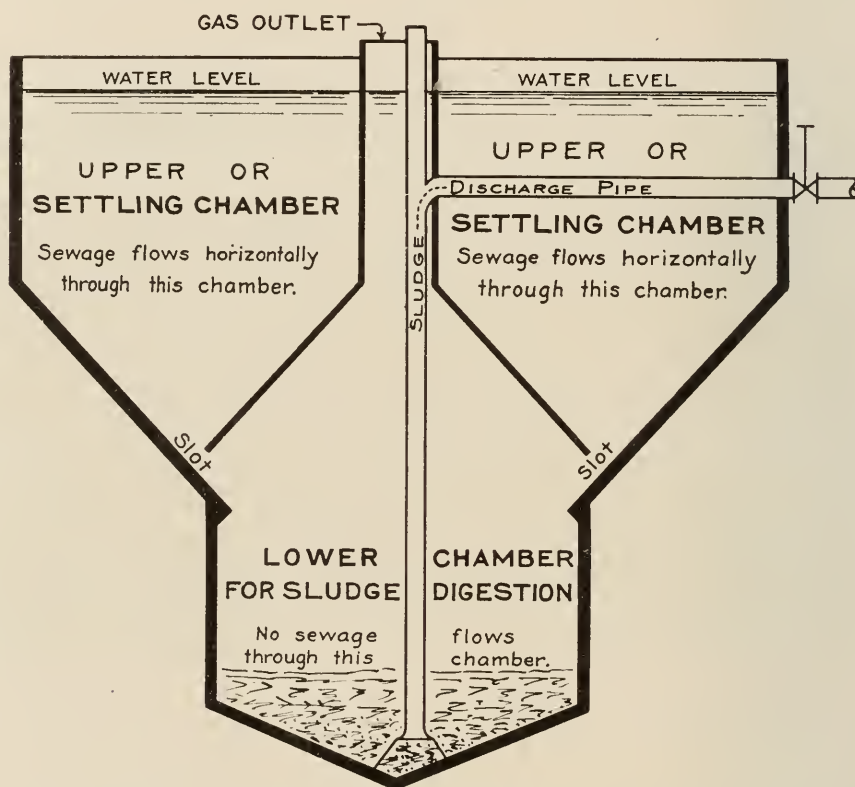
The question has frequently been raised as to whether or not the first flow of the rain-water, which generally carries manure and dust from the streets of a city and a great many bacteria deposited upon the street surface, should be carried into the sewers or kept separate in the storm-water drains. Dr. William Dunbar, of Hamburg, very carefully determined the condition of the street water at the beginning and at the end of a storm. He found that at the beginning the water was as foul as the sewage in the sewers. It is very desirable, therefore, if it can be practically done, that in the case of a separate system the first wash from the streets be taken into the sewers, so that it can be treated with the sewage. This expedient is followed in some

cities in Europe, and I think that in the future it will be followed more frequently in our country than heretofore.

Another most important part of a city sewerage system is the final disposal of the sewage. This should be accomplished in a manner so that it will not be harmful nor unpleasant. We should, therefore, soon determine upon a place of final discharge and a method of treatment to which it should be subjected.

Such a treatment may be complex. We have to consider

FIG. 6.



Vertical section through Imhoff tank at right angles to the direction of sewage flow.

disease germs on account of the danger to health, and the putrefying matter so far as a nuisance is concerned. We have further to distinguish between the most economical ways to prevent both of these troubles.

One part of the sewage is solid matter in suspension, and the other part is liquid matter together with fine suspended matter which will not readily settle out but remains in the liquid and causes it to be more or less turbid.

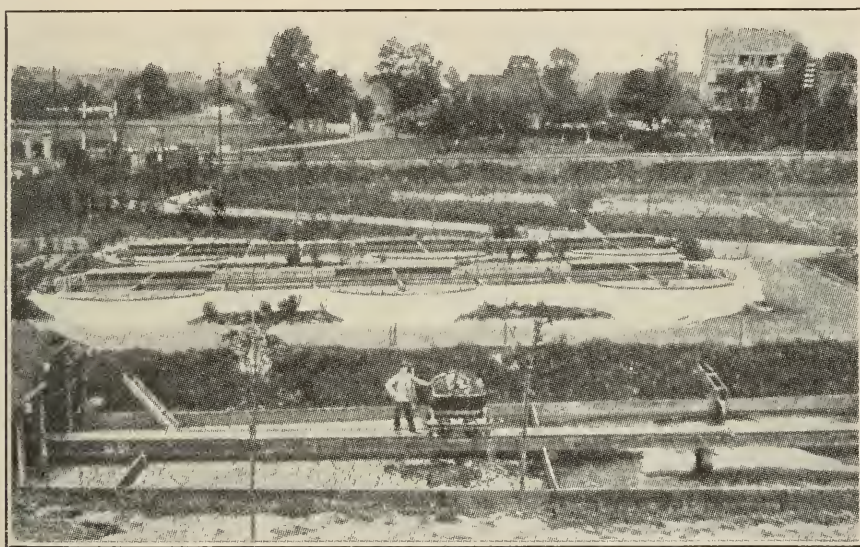
For the purpose of any subsequent treatment it is best to divide

the sewage into these two parts, because the treatment of the solids demands an entirely different process from that of the liquids.

The first thing to be done, therefore, when sewage is to receive any treatment, is to allow the suspended matter to be held back and separated from the liquid matter, so far as this is practicable.

The collection of the solid matter is accomplished by screens and by sedimentation. Many sewers, when they discharge into rivers, have screens near their outfalls causing the larger matters to be retained, taken out, and separately disposed of. Sometimes

FIG. 7.



Imhoff tanks and sludge-drying beds at Recklinghausen, Germany, population 30,000. Note proximity of dwellings.

this matter is pressed, squeezing out much of the liquid, and the remaining matter is either buried or burned.

Where screening is not adopted there is no way of keeping out the floating matter, except by retaining the sewage in large basins in which the floating matter gathers at the top and from where it can be removed at the surface. The retention of the sewage also causes the heavier matters to deposit.

When the oxygen in the sewage is exhausted the deposited matter or sludge begins to putrefy, and the evolution of gases causes the entire mass of sewage and sludge to become putrescent or septic and emit strong odors. Many studies have been made

and perhaps a hundred patents have been taken out relating to the treatment of this sludge so that the results would be acceptable both from the standpoint of cost and nuisance.

The most common treatment has been to put the sludge upon fields, where it was dried, ploughed in, or covered with lime, etc. It has also been pressed, mixed with strong fertilizers or pulverized and used as manure.

In order to have a more complete removal of the suspended matter from the sewage, lime was added to the water. The resultant sludge, increased in quantity, was then usually dumped or pressed into solid cakes, for use as fertilizer.

FIG. 8.



Imhoff tanks at Essen, Germany, population 180,000. Note proximity of dwellings.

All the processes of treating sludge were, however, not very satisfactory because of the resulting stench. Yet they had to be recommended as the best known expedients, and on account of the offensive odor it was necessary to locate the treatment works far away from the inhabited parts of the cities. Only a few years ago the city of Baltimore bought a strip of land about 1000 feet wide outside of its works in order to obviate any nuisance.

About eight years ago a German engineer erected some experimental plants at Essen, modelled after the experience gained at the sewage fields near Hampton, England, where Dr. Travis had been making some promising studies. The Essen experi-

ments, undertaken by Dr. Imhoff, resulted in the discovery of a means of securing a collection and a treatment of the sewage sludge that was not offensive.

This process is now known as that of the Imhoff tank treatment. Varying the process from that used at Hampton, by preventing any circulation in that part of the tank where the sludge is deposited and where it ferments, Dr. Imhoff has succeeded in establishing a decomposition confined to the biological action of such classes of bacteria which develop substantially only marsh gas and carbon dioxide gas, neither of which has an odor.

It is known that if no fresh sewage flows over decomposing

FIG. 9.



Sludge dump for dry sludge after removal from drying beds.

sludge, to supply it with miscellaneous sewage bacteria, the controlling bacteria in the sludge are confined substantially to but two classes; namely, those producing the two inoffensive gases just mentioned.

The Imhoff tank consists of practically two tanks, one over the other. Through the upper one the sewage flows with a velocity reduced so much that its suspended matter will settle. It requires a passage through the tank of from $1\frac{1}{2}$ to $2\frac{1}{2}$ hours. This matter is allowed to slip through a slot into a lower chamber in such a way that no possibility exists for any solid matters to rise and again mix with the fresh sewage passing by in the upper tank. There are special shafts provided for the ascent of

any fat or light matter, which should rise with gas bubbles from the lower chamber, and to form a scum in the shaft, to be removed when necessary. This scum is usually small in amount and could be readily removed if it becomes excessive. It has no objectionable odor in any of the existing plants (see Fig. 6).

The accumulating sludge in the lower tank, when it has become ripe and the existing sulphur bacteria have been practically exterminated, has no odor. This can be found by extracting some of it from different depths. According to the character of the sewage, it requires about three to five months to be de-

FIG. 10.



Dried sludge from Imhoff tanks sold to farmers for fertilizer.

composed sufficiently so that it will not become putrescent when again exposed to the air. The decomposed sludge is withdrawn from the bottom of the tank automatically, and, being deprived of its slimy, putrescible matter, it is friable and porous, looking very much like garden soil, to which it is very similar. The latter has been formed from the leaves and branches without putrefaction and with the evolution of the same inoffensive gases, such as marsh gas and carbon dioxide, which produces the decomposition in the Imhoff tanks. It rapidly drains out its superfluous water, and dries in well-drained beds within a week sufficiently to be spaded and removed.

There are over 100 plants in operation in Germany and this

country, and reports indicate that in none of them which are properly operated does the sludge have an offensive odor. In our country the largest plant is in Atlanta, Ga., and there is one at Holmesburg, Philadelphia, below the Torresdale Water Filtration Plant.

It is gratifying, therefore, that we have now a means of treating the sludge so that it will not be offensive, and we believe that by the same process the disease germs contained in the sludge will have perished by the time it is extracted and dried.

Before sewage reaches the tanks it is advisable, particularly where the sewage contains street wash, to take out any gravel or sand (*i.e.*, grit). This deposition is secured in a special small chamber where the velocity of the sewage is reduced to about 12 inches in a second. This reduction will cause the grit to deposit and the rest of the suspended matter, which contains the foul matter, to pass on to the settling chambers. In these tanks the velocity is much more reduced, generally to about one-tenth inch per second. This comparatively quiescent state causes the deposition of practically all of the foul suspended matter which forms the bulk of the sludge. We use the term "settleable" matter because there is not deposited the fine suspended matter which may cause putrefaction and which must be treated together with the dissolved organic matter.

In order to increase the quantity of settleable sludge, experience has shown that by adding a precipitant to the sewage a large percentage of this fine matter and even some of the dissolved matter can be coagulated and also settle into the lower tank. In the latter case the effluent sewage is much clearer, but the size of the lower tank must be correspondingly increased on account of the added sludge and precipitant. It is, of course, a question to be determined in each case as to whether or not it is necessary or wise to add a chemical precipitant.

You have all heard of the septic tank. This was first used under this name in the city of Exeter, England, and it was found that in a single basin where the sewage was retained at least 8 hours most of the suspended matter was deposited on the bottom and underwent putrefaction. It was allowed to remain in the tank until fairly well rotted out, which generally took at least a year.

This was a process of putrefaction which produced chiefly

sulphuretted hydrogen, and, therefore, not only the liquid but also the putrefying sludge sent up bubbles of offensive gas. Notwithstanding this fact, septic tanks have been very extensively used on account of their relative economy as compared to other processes, and it was even heralded as the long-expected final solution of the sludge question. A good deal of the sludge disappeared, so that in a few cases but 10 per cent. of the original quantity was left; in most cases the record is from 25 to 50

FIG. 11.



Revolving sprinkling filters at Wilmersdorf, Germany.

per cent. The reduction in the quantity of sludge handling was the chief attraction of this process.

On account of the odor septic tanks were isolated and kept far away from inhabited sections of a city. In the city of Saratoga, N. Y., there is a well-devised system of sewers and of sewage treatment, with possibly the best instalment of a septic tank in this country. The odor from the tank, however, is very strong. In one of the suburbs of Berlin (namely, Wilmersdorf) septic tanks are also used with very similar results. The odor from the tanks was found to be perceptible over a mile away.

We cannot place much reliance on the figures given as to the reduction of the sludge, because so much depends upon the amount of water contained therein. If we have originally 95 per cent. of water in the sludge and reduce the same to 90 per cent. we have diminished the quantity of sludge practically one-half. This fact makes it necessary, when comparing quantities of sludge, to compare also their percentages of water.

The sludge of the septic tank is of a different character from that of the Imhoff tank. It is not as thoroughly decomposed, generally retains a large amount of fine and slimy matter with a

FIG. 12.



Sprinkling filter at Atlanta, Ga.

large amount of water, and after withdrawal does not become spadeable sometimes for several months.

The last subject to be mentioned is the treatment of the liquids after they have been freed from the settleable suspended matter by passing through the tanks. There are still generally left a substantial amount of fine suspended particles and a large amount of dissolved organic matter. The oxygen contained in the water is rapidly extracted.

If the sewage is discharged into a running stream, and if there is enough oxygen in it to oxidize its organic matter, a decomposition of the organic matter will take place in the water. This method of oxidation in running streams is a practicable and legitimate means of oxidizing liquid sewage. It is just as rational

as an oxidation on land. We are, therefore, not justified in seeking the entire exclusion of all sewage from rivers where they can be utilized for oxidation, both economically and without offence.

We must not forget, however, that nuisance is not the only question to be considered. We must prevent also all objection due to the injury of fish and shell fish and to a possible danger from bathing, and in no case can such water, which has received sewage, be used for drinking purposes, unless it is first purified.

FIG. 13.



Intermittent sand filter for sewage at Stockbridge, Mass., showing distributing channels.

We must also not forget that river water may be polluted as much from the natural land washings and city washings during a rain storm as from liquid sewage.

Nearly all of the large cities of the world dispose of their sewage by river dilution. In some cases this process is not properly carried out: the solid matter of sewage is admitted in too large proportions, and sludge remains in the rivers by sedimentation. Sometimes, also, more liquid sewage is discharged than can be properly oxidized by the water. Yet, after the floating

matter and sludge have been removed, before sewage is discharged into a river, and if the river contains enough oxygen, there can be no objection to utilizing nature's means of purifying organic waste matter in this very economical way.

If there is no river, or if the river is not large enough to promptly dilute the amount of sewage in question, and if there is trouble anticipated regarding fish life, then it is necessary to purify some and often all of the sewage on land.

There are many processes of such purification on land which have been tried, particularly in England. It will not be necessary to mention them all, because most of them have been abandoned. To-day there are really but two processes in use: a treatment by coarse-grained filters and a treatment by sand filtration.

The coarse-grained filters are built of material from the size of a walnut to the size of a fist, and of depths varying from 5 to 10 feet. The sewage is delivered upon the top in various ways. In all cases it must be sprinkled either from stationary or movable jets, because otherwise the large pores of the bed would let it rapidly run through. The sewage percolates through the bed by slowly flowing on the surfaces of the grains from one to the other until it reaches the bottom. Upon these grains or stones is a slimy coating which harbors myriads of bacteria. These take from the passing sewage the organic matter which is in solution and convert it into inoffensive and inert matter. While the water may be quite putrescible when sprinkled on, it leaves the filter, if this is properly devised, without putrescibility; *i.e.*, in a condition so that it will not become foul.

The process of sand filtration is virtually the same as just described. The grains are much smaller and, therefore, the liquid can flow directly upon the bed for distribution instead of being sprinkled. The speed of percolation is much slower and, therefore, the purification is greater. Bacteria do the converting in both cases.

Both coarse- and fine-grained beds are underdrained to allow of a free discharge of the effluent, and both should have a free circulation of air between the grains to supply the oxygen which is necessary to convert organic matter.

(A large number of lantern slides were then shown upon a screen and explained. A few of them are here reproduced with brief explanations.)

Detinning Methods. U. S. CONSUL, GEN. R. P. SKINNER, Berlin. (*The Metal Ind.*, xii, No. 8, 326.)—The recovery of tin from tin-plate waste has recently gained great importance. There are three general methods of separation—mechanical, chemical, and electrolytic. In the mechanical process, which gives only poor results, the tin is melted or thrown off during heating. In chemical separation the tin-plate waste is treated at a low temperature with dilute hydrochloric, nitric, or sulphuric acid, and the tin and zinc are dissolved. The most important method is the electrolytic. As a rule, the electrolyte is hot caustic soda, 6 to 7 per cent. Na_2O . Loose chips of tin packed in wire baskets are the anodes, while the iron bath walls, or iron plates suspended therein, serve as cathodes. The average tension is 1.5 volts. The separated tin is spongiform. Another process has an acid electrolyte, 1 volume of 60 per cent. sulphuric acid to 9 volumes of water. Chips of tin plate in wooden latticed baskets serve as anodes, and tinned copper as cathodes. The density of current is about 100 ampères to the square metre. The electrolytic methods using acid and ferrosulphate electrolytes have not shown any practical value. The greatest amount of tin-plate waste is detinned by the chloride method of Lambotte, of Brussels. The principal requirements for a successful application of this method are absolute exclusion of moisture during the process of detinning, avoidance of an unduly high temperature, and proper washing of the detinned waste. Lambotte's method is described in Imperial German letters patent No. 32517.

The Melting-point of Arsenic. W. HEIKE. (*Int. Zeits. Metall.*, vi, 168.)—Heating and cooling curves of arsenic contained in an exhausted porcelain vessel packed in sand in an iron bomb gave a melting-point of 830°C . No other thermal effects were noted between 150°C . and this temperature. The arsenic, after being melted, was steel-gray to lead-gray in color; it was very brittle and broke easily with a brilliant fracture; the hardness on Moh's scale was $3\frac{1}{2}$ to 4.

Light from Unconsumed Electrodes. A. VOSMAER. (*Met. and Chem. Eng.*, xii, 377.)—If the discharge from a Ruhmkorff induction coil equipped with a modern Wagner hammer be made to pass between two nickel wires about 2 mm. apart, the ends will burn and form globules. If now the distance is increased to 3 to 4 mm., the wires will continue glowing without further adjustment. No oxidation or vaporization takes place, as the distance between the wires remains the same, and spectroscopic examination shows a continuous spectrum without lines. Platinum wires melt rapidly under the same conditions. If a copper wire is substituted for one of the nickel wires, the nickel electrode glows, while the copper electrode remains dark.

RECENT DEVELOPMENTS IN THE ART OF ILLUMINATION.*

BY

PRESTON S. MILLAR,

Electrical Testing Laboratories, New York, N. Y.

IN the JOURNAL OF THE FRANKLIN INSTITUTE for the last few years there are to be found a number of papers dealing with certain phases of illumination. These are of especial interest to a limited number of Institute members, but most of them are somewhat esoteric and presumably have been read in detail by but a limited number of Institute members. Consideration of the character of the Institute membership has led the writer to feel that he could perhaps be of some service by endeavoring to outline in a comprehensive way the nature and scope of the art of illumination and by making available a brief review of developments in illumination which will place before the members a general view of the subject in its large features. Accordingly, this paper will be found to contain but little of new interest for the illuminating engineer, being written more especially for the consideration of the membership of the Institute at large.

In the discussion which follows a fragmentary bibliography is included. The references which are noted are intended to direct attention to significant papers, and to furnish an indication of the manner in which the several phases of each division of the subject of illumination are being developed.

Illuminating engineering as a distinct specialty is perhaps not generally understood. The name illuminating engineering as applied to this specialty is perhaps not wisely chosen. It will serve, however, for the purpose of this discussion. Illuminating engineering, then, as a specialty may be represented by the diagram in Fig. 1.

The specialist applies the materials of illumination with the aid of the science of illumination, and practises the art of illumination.

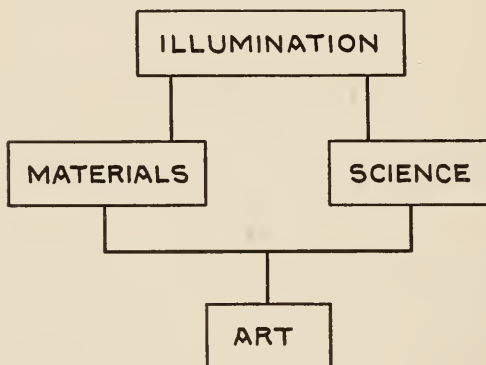
* Presented at a joint meeting of the Electrical Section and the Illuminating Engineering Society, held Thursday, April 9, 1914.

THE MATERIALS OF ILLUMINATION.

The *materials of illumination* may be classified as illuminants—natural and artificial—lighting auxiliaries, and fixtures.

Considering first *incandescent electric lamps*,¹ it may be noted that increases in the efficiency of light production have been ac-

FIG. 1.



companied by increase in the variety of illuminants both as to types and sizes. Neglecting for the moment other qualities than the efficiency of light production, your attention is directed to the

FIG. 2.

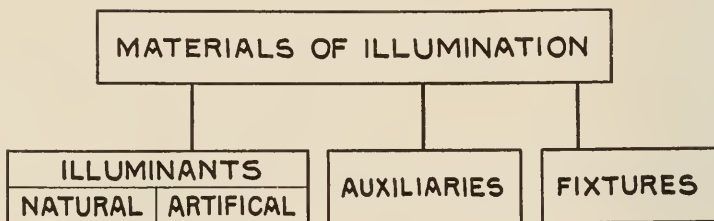


diagram in Fig. 3. This shows improvements in incandescent electric lamps which were made available some years ago and the status of lamps of more recent development. It will be noted that the advances in the efficiency of light production have been

¹ *Incandescent Lamps:*

"A New Carbon Filament," Howell, *Trans. A. I. E. E.*, 1905, p. 839.

"New Types of Incandescent Lamps," Sharp, *Trans. A. I. E. E.*, 1906, p. 815.

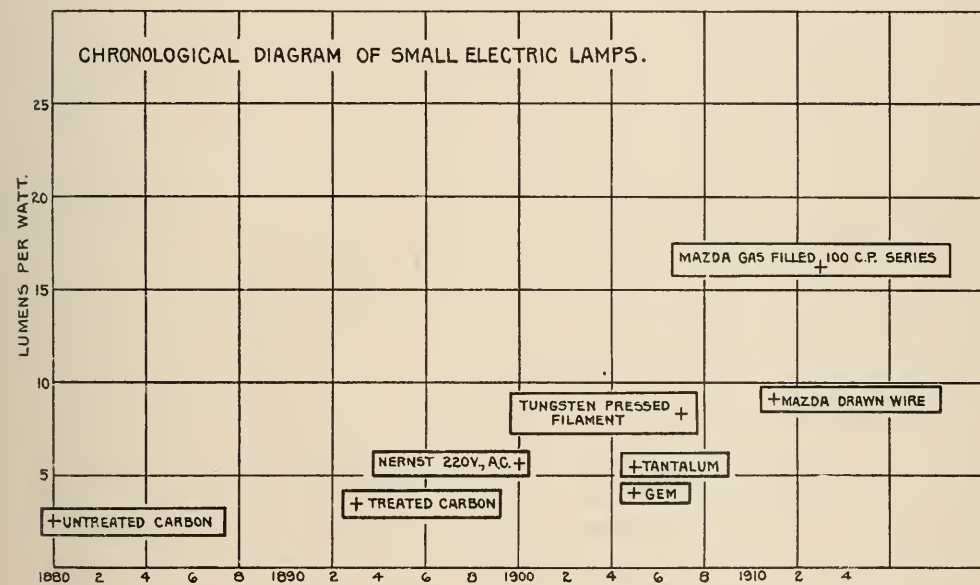
"High Efficiency Lamps," Doane, *Proceedings N. E. L. A.*, 1910.

"Recent Progress in the Art of Lamp Making," Randall, *N. E. L. A.*, 1913.

"Tungsten Lamps of High Efficiency," Langmuir & Orange, *Trans. A. I. E. E.*, 1913, p. 1915.

marked. The carbon filament lamp which had remained without material efficiency improvement from 1893 to 1905 was at that time improved through the development of the so-called "metallized" carbon filament, and in that form remains the most efficient type of carbon filament incandescent lamp. The carbon filament lamp had been the standard form for general electric lighting, and continued to be the standard lamp and the most largely produced lamp until about 1912. Its preëminence was challenged before that time because of the adoption of the metallized carbon filament lamp for free renewal to customers by the

FIG. 3.



larger central stations of the country, and was lost in 1912 as a result of the influence of lamp manufacturers in promoting the sale of the metallized filament rather than the sale of the carbon filament lamp. The substitution of the metallized carbon filament lamp for the earlier form of carbon filament lamp resulted in an increase of the standard of illumination throughout the country, for it consumed the same energy and produced about 20 per cent. more light than did the earlier carbon filament lamp.

In 1905 the various forms of carbon filament lamps were supplemented by the tantalum lamp, an importation from Europe. This lamp never entered largely into American practice, its largest sale in the country probably never exceeding 3 per cent. of the total sales of incandescent lamps. Its inferiority when operated

upon alternating current and the announcement of the invention of the tungsten lamp shortly after its appearance, prevented its attaining a position of importance in our practice.

The tungsten filament lamp, first made available commercially in 1907, was a marked improvement over other lamps then available, although its fragility and relatively high price led to restriction of its use in the earlier years of its history. Through the splendid development work of American lamp manufacturers, this lamp has been rendered much more effective in all respects than it was a few years ago. The substitution of the drawn wire mounted as a continuous filament placed the lamp in a class with the carbon filament lamp in respect to ruggedness. The development of bulb blackening preventives has permitted its operation at somewhat higher efficiencies. These improvements, with notable price reductions, have led to the large use of the tungsten, now known chiefly as the Mazda lamp, so that in 1913 sales of the Mazda lamp exceeded sales of all other types of incandescent electric lamps, notwithstanding the fact that the life standard which it sets is twice that which obtained previously.

During the past year, a new form of tungsten filament lamp has been announced, in which the bulb contains an inert gas which reduces the rate of evaporation of the filament and permits operation of the lamp at a higher efficiency. This gas-filled Mazda lamp is chiefly of importance in the larger sizes, and in effect creates a new lamp of characteristics similar to the incandescent lamp but of power equivalent to the arc lamp. In its smaller sizes it is included on the diagram, marking the highest efficiency attainment in the production of light by small incandescent lamps.

The Nernst lamp was brought to its highest development in 1908 in the Westinghouse Nernst. Its active exploitation practically ceased in 1912, due to the superior qualities of the tungsten filament lamps.

Paralleling the improvement in efficiency of light production by means of incandescent lamps have come improvements in *larger electric illuminants*.² The pure carbon open arc lamp was

² *Arc Lamps:*

“The Invention of the Enclosed Arc Lamp,” Marks, *The Sibley Journal of Engineering*, October, 1907.

“Properties and Industrial Applications of the Flame Arc Lamp,” Blondel, *International Electrical Congress*, 1904, vol. 2, p. 729.

supplemented in about 1893 by the enclosed carbon lamp, which largely supplanted it in spite of a lower efficiency because of more desirable operating characteristics. This enclosed carbon arc lamp has been for a number of years the standard street lighting illuminant of America, and only within the past two or three years has yielded its position of preëminence in that field to the newer and superior forms of arc lamps. The intensified carbon arc lamp has found considerable application in the lighting of interiors, principally stores. In this lamp pure carbons of relatively small diameter are operated at high current density within a globe which partially restricts the air supply. The resultant light is more nearly white than that usually obtained from the carbon arc lamp and offers some advantages for store lighting purposes.

The metallic electrode arc lamp, of which the Magnetite and Metallic Flame lamps are the principal examples, has come into large use in street lighting and more than any other type of lamp has supplanted the enclosed carbon arc lamp. This lamp differs radically from earlier forms of arc lamps in that the light is produced by luminescence and emanates wholly from the arc stream, whereas in the several forms of pure carbon arc lamps the light is produced by incandescence of the electrode ends.

The flame arc lamp (short life form) is the highest achievement in efficiency of light production among commercial electric illuminants. In its earlier forms it suffered from short electrode life, which made its operation costly and practically limited its usefulness in this country to display lighting. In repetition of the history of the pure carbon arc lamp, the flame arc lamp, which is equipped with carbons impregnated with various salts, has been adapted to secure long electrode life by partially enclosing the arc and employing large diameter electrodes. As in the earlier lamp, this operating advantage has been secured at the expense of loss

"The Electric Arc," Steinmetz, *International Electrical Congress*, vol. 2, p. 710.

"The Metallic Flame Arc Lamp," Stephens, *Trans. Illg. Eng. Soc.*, 1907, p. 657.

"Design of Luminous Arc Lamps," Halvorson, *General Elec. Review*, 1911, p. 578.

"Arc Lighting," Steinmetz, *General Elec. Review*, p. 568, 1911.

"Ornamental Luminous Arc Lighting at New Haven," Halvorson, *General Elec. Review*, 1912, p. 220.

"Enclosed Flame Arc Lamp," Chamberlain, *General Elec. Review*, 1912, p. 706.

in efficiency, and the long-burning flame arc lamp is not to be confused with the more efficient short-life flame arc lamp in this respect.

The gas-filled Mazda lamp,³ small sizes of which have been included in consideration of incandescent lamps, has not yet emerged from the developmental stage, but is known to be among the very highest efficiency electric illuminants, especially in its larger sizes.

The mercury arc lamp is available in two types. The low-pressure arc in glass tubes is the earlier form and is in more general use than the high-pressure quartz tube lamp. The latter, however, surpasses it in efficiency.⁴

The Moore tube, filled with nitrogen for general illumination purposes, has been used to a limited extent for special classes of lighting. Smaller sizes in which carbon dioxide replaces nitrogen are used only as artificial daylight.

The Neon tube, as devised by Claude of France, marks a distinct advance in the efficiency of tube lighting. Whereas the Moore nitrogen-filled tube yields light of a pinkish-yellow tinge, the Neon tube gives light which is red.⁵

The diagram, Fig. 4, summarizes and compares the light-producing efficiency of these several large illuminants. The enclosed carbon arc lamps and the Moore tube are the lowest in efficiency. The 4-ampère Magnetite lamp is of substantially the same efficiency as the old open carbon arc lamp. The 6.6-ampère Magnetite and the low-pressure mercury vapor lamp are next in order, just failing to reach the efficiency of the long-burning flame arc lamp, of the quartz high-pressure mercury vapor lamp, and the Mazda gas-filled lamp. A short-burning flame arc lamp producing 36 lumens per watt is distinctly the most efficient of these large illuminants.

³ *Mazda Gas-Filled Lamps:*

"Tungsten Lamps of High Frequency," Langmuir and Orange, *Trans. A. I. E. E.*, 1913, p. 1915.

⁴ *Mercury Vapor Lamps:*

"Notes on the Cooper-Hewitt Lamp," Cooper-Hewitt, *Elec. World and Engineer*, 1910, p. 679.

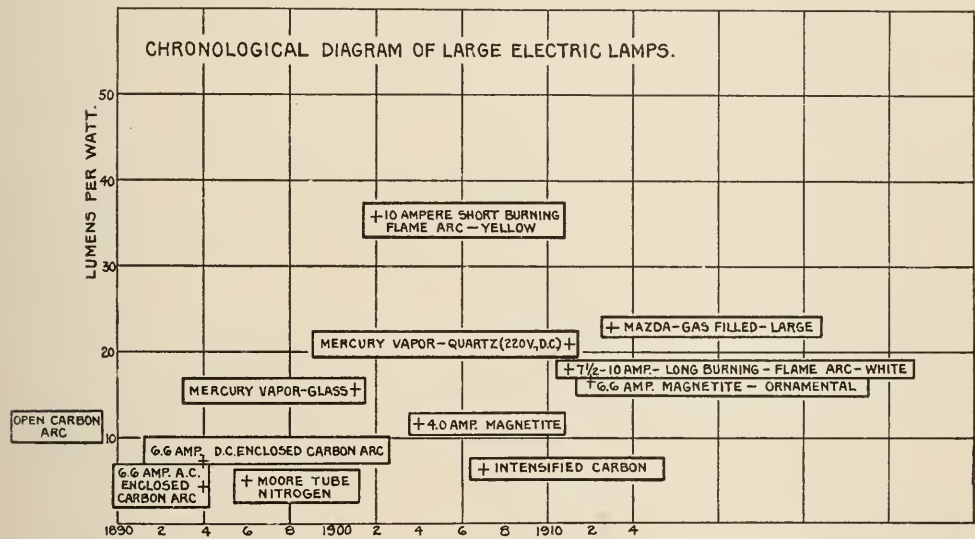
⁵ *Tube Lighting:*

"Light from Gaseous Conductors within Glass Tubes," Moore, *Trans. A. I. E. E.*, 1907, p. 605.

"Neon Tube Lighting," Claude, *Trans. Illg. Eng. Soc.*, 1913, p. 371.

The development of the *gas mantle* by Von Welsbach, in 1884, was the beginning of a new era in gas lighting.⁶ When the mantle burner was introduced, there were available the flat flame burner, producing 1 to 2 candlepower per cubic foot of 16-c.p. coal gas; the Argand burner, producing perhaps 3 candlepower per cubic foot; the regenerative burners producing as much as 7 to 10 candlepower. The Welsbach lamp made available at first 10 and later something like 15 candlepower per cubic foot of gas. Since the early developments of the modern Welsbach lamp in say 1891, no material improvements have been made in the effi-

FIG. 4.

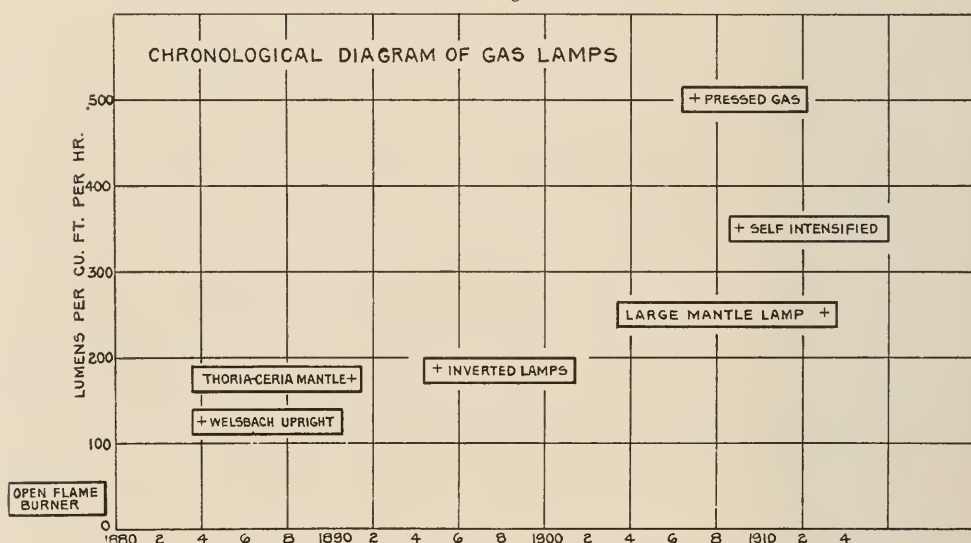


ciency of light production from small mantle burners, though burners, mantles and auxiliaries have been further developed along lines which make for better operating qualities. Beginning with about 1901, the number of sizes of lamps employing mantles was increased and the production of an inverted burner was undertaken. By 1906 the inverted burner had attained a point of commercial success, and there had been produced a variety of sizes of upright mantle lamps, ranging from those consuming 1 1/4 cubic feet of gas up to the multiple burner lamps employed for lighting

⁶ *Gas Lamps*:
“Inverted Gas Lighting,” Whitaker, *Trans. Illg. Eng. Soc.*, 1907, p. 764.
“Modern Gas Lighting Conveniences,” Little, *Trans. Illg. Eng. Soc.*, 1908, p. 418.
“Symposium on High-Pressure Gas Lighting,” Goodenough, Klatte and Zeek, *Trans. Illg. Eng. Soc.*, 1912, p. 506.

large areas, and consuming 12 to 18 cubic feet of gas per hour. Since that time this range of lamps has been realized in the inverted type and various improvements have been made in structural features and operating qualities. Regenerative lamps have been produced and have entered to a limited extent into service in this country. These attain efficiencies of the order of 28 candlepower per cubic foot per hour. Highest efficiencies from illuminating gas have been obtained by the use of pressed gas systems, used largely abroad for street lighting, but not as yet introduced extensively in this country. These yield light-producing efficiencies of the order of 35 candlepower per cubic foot per hour.

FIG. 5.



The progress in efficiency of light production indicated by the record of the manufacturer of gas illuminants is shown in Fig. 5.

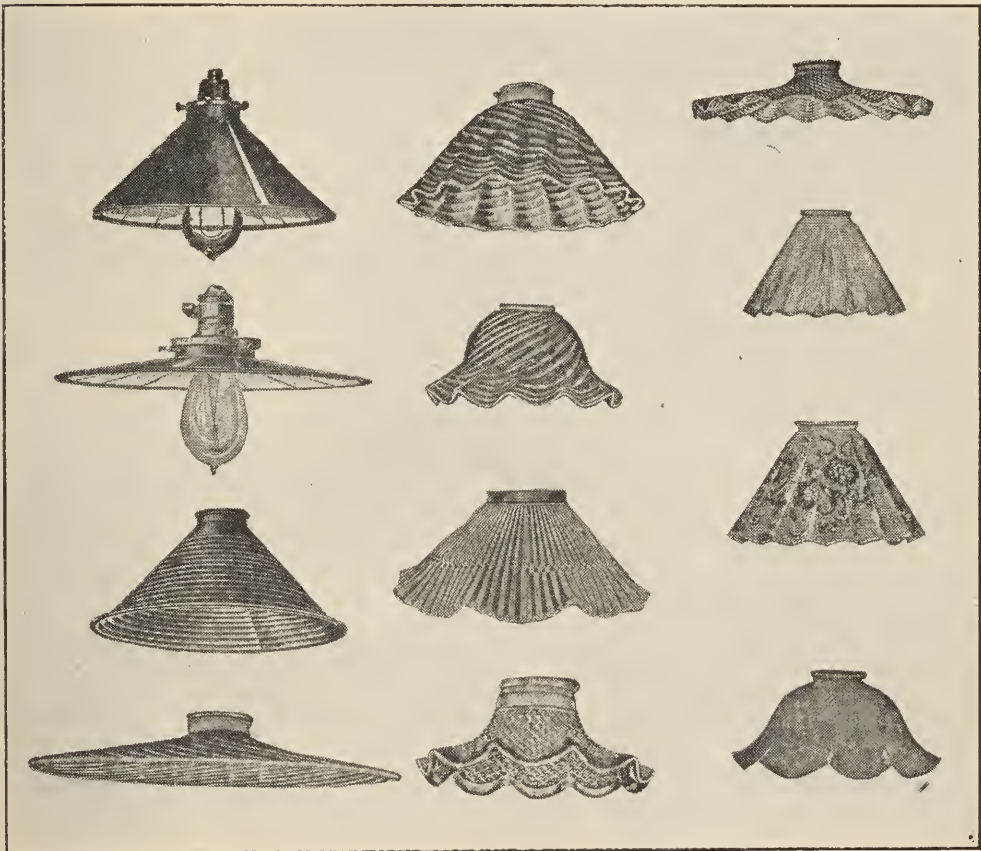
Among *other illuminants*⁷ the kerosene oil lamp is, of course, the most important. Its earlier form was improved by the substitution of a round wick, centre draught lamp for the flat wick burner. The incandescent mantle has been applied to the kerosene lamp but without such success as to command general substitution in oil-lamp lighting. Acetylene lighting, filling a limited part of the general illumination field, is not understood to be making any considerable advance in efficiency of light production. The same is true of gasoline lighting.

⁷ *Miscellaneous Illuminants:*

"The Progress of the Gas Industry," Morrison, *Trans. Illg. Eng. Soc.*, 1909, p. 36.

One illuminant has been produced which yields light of a color closely approximating what may be considered to be average daylight. That is the Moore carbon-dioxide tube. Mazda lamps, the intensified carbon arc lamp, and gas mantle lamps have been equipped with color screens intended to modify the light to pro-

FIG. 6.



Reflectors of a decade ago.

duce artificial daylight.⁸ Some of these duplications of natural light are excellent and are being employed with good effect for commercial purposes. Other illuminants or equipments for illu-

⁸ *Artificial Daylight Illuminants:*

"A Standard for Color Values—The White Moore Light," Moore, *Trans. Illg. Eng. Soc.*, 1910, p. 209.

"A Lamp for Artificial Daylight," Hussey, *Trans. Illg. Eng. Soc.*, 1912, p. 73.

"Subtractive Production of Artificial Daylight," Ives and Luckiesch, *Electrical World*, 1911, p. 1092.

"A Gas Artificial Daylight," Ives and Brady, *Lighting Journal*, 1913, p. 131.

minants have been announced as the equivalent of daylight or as having daylight qualities. Unfortunately, however, there has been much misrepresentation connected with this, and so far as the writer is aware, only the efforts named above should be regarded seriously in this connection.

FIG. 7.



Various forms of modern reflectors and globes.

Lighting auxiliaries,⁹ including reflectors, globes, shades, etc., have been greatly improved in recent years. Fig. 6 illustrates some types of reflectors typical of those which were sold 10 to 15

⁹ *Auxiliaries*:

"The Principles of Shades and Reflectors," Bell, *Trans. Illg. Eng. Soc.*, 1909, p. 723.

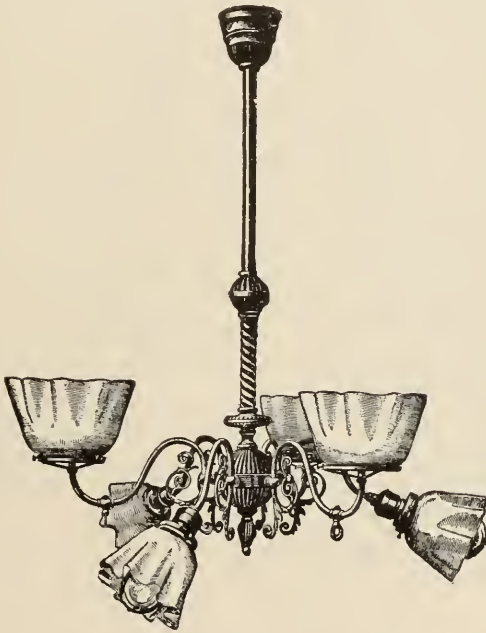
"Scientific Principles of Globes and Reflectors," Lansingh, *Trans. Illg. Eng. Soc.*, 1910, p. 49.

"Symposium on Illuminating Glassware," Jones, Marshall, Young and Hibben, *Trans. Illg. Eng. Soc.*, 1911, p. 854.

years ago. Fig. 7 shows an assortment of modern reflectors which surpass those previously available in appearance, and in that they conceal the light source and diffuse the light. They excel also in efficiency of light redirection.

The design and manufacture of *fixtures*¹⁰ may be divided into two classes; namely, fixtures of distinctive design and stock fixtures. The former cannot well be generalized; the latter, which, of course, are more largely used, have been improved somewhat with the improvement in taste in regard to design which is grad-

FIG. 8.



Typical stock fixtures of a decade ago.

ually being wrought among the public at large. At least, it may be said, that the atrocious fixtures which were placed in moderate priced houses twenty years or so ago are now supplanted by more tasteful fixtures.

Fig. 8 shows a cluster of electric lamps which is typical of those sold ten years ago. Contrast them with the view in Fig. 9

¹⁰ *Fixtures*:

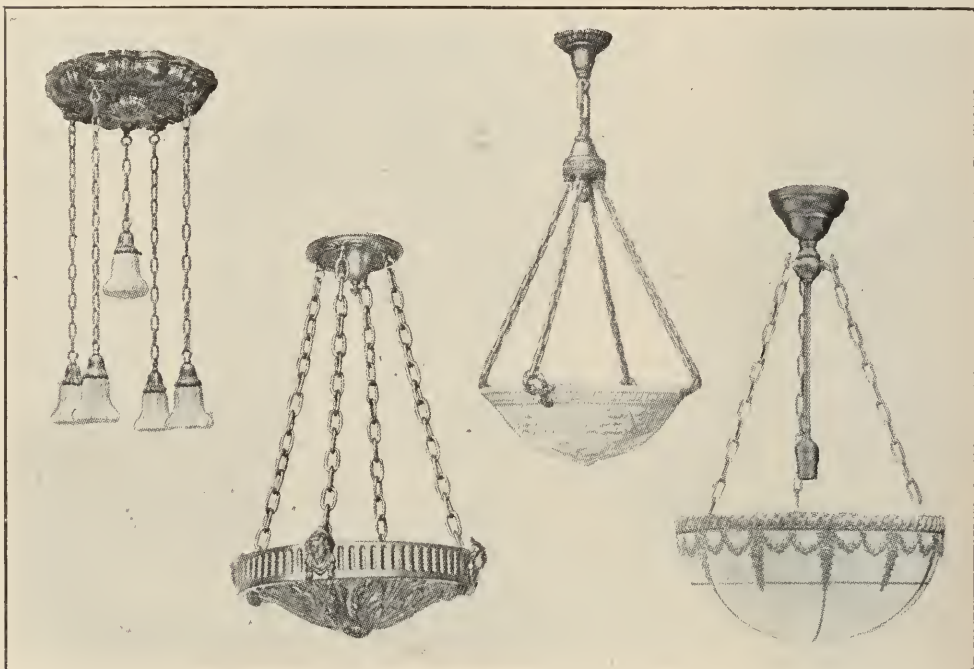
"Fixture Design," Lansingh and Heck, *Trans. Illg. Eng. Soc.*, 1907, pp. 728-784.

"The Relation of Fixture Design to Modern Illuminating Practice," Hopton and Watkins, *Trans. Illg. Eng. Soc.*, 1910, p. 310.

of modern fixtures designed for the same class of use. The latter are superior in almost every respect, and while possibly more costly, yield a much better service return upon the investment.

It is thus apparent that progress in recent years in the design and construction of materials of illumination has been rapid, and that the report of recent developments must be considered to be

FIG. 9.



Modern fixtures.

encouraging in so far as the materials of illumination are concerned.

THE SCIENCE OF ILLUMINATION.

The *science* of illumination may be considered to comprehend engineering, vision, and æsthetics.

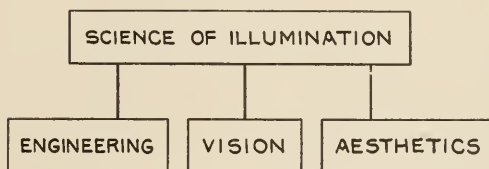
Principles of Engineering.—Considering first the principles of engineering in so far as they form a part of the science of illumination, it may be said that the subject of *supply* falls properly under the headings of electrical or gas engineering. The lighting practitioner must have a working knowledge of usual systems of supply, but no special knowledge is essential.

In the matter of *installation*¹¹ the practitioner needs to be somewhat more skilled. The electrical contractor, plumber, etc., are prepared to handle installations effectively, but are in need of guidance of the illuminating expert; hence, the latter requires a good working knowledge of the subject.

A thorough knowledge of the design, construction, lighting qualities, and operating characteristics of *artificial illuminants* is essential, and this subject has not been neglected in the literature of the art. *Daylight*¹² also has been studied as to direction, diffusion, intensity, color, etc. Very complete information regarding sources of illumination is thus available to the practitioner.

The study of *auxiliaries* from the several viewpoints of light distribution, light absorption, color modification, dust deprecia-

FIG. 10.



tion, etc., has been an important part of recent developments in the field of illumination. The light distribution curve has become a familiar part of manufacturers' data and has been influential in emphasizing the importance of correct design and low light absorbing qualities for reflectors and globes. It has been shown that there have been marked improvements in the design of lighting auxiliaries. Likewise, there has been a notable growth in the knowledge of the use of such devices and in the discriminating selection of the best available for given purposes.

¹¹ *Operating Characteristics of Illuminants:*

"Deterioration of Gas Lighting Units in Service," Pierce, *Trans. Illg. Eng. Soc.*, 1912, p. 677.

"The Relation of the Incandescent Lamp to the Lighting Service," Cooper and Campbell, *National Elec. Light Assn.*, 1913, p. 400.

"The Proper Lamp for a Circuit," Campbell and Cooper, *N. E. L. A.*, 1912, vol. 3, p. 338.

¹² *Daylight:*

"Daylight Illumination," Marsh, *Trans. Illg. Eng. Soc.*, 1908, p. 224.

"The Intensity of Natural Illumination Throughout the Day," Lewinson, *Trans. Illg. Eng. Soc.*, 1908, p. 482.

"The Distribution of Luminosity in Nature," *Trans. Illg. Eng. Soc.*, 1911, p. 687.

"Daylight," Nichols, *JOURNAL OF THE FRANKLIN INSTITUTE*, 1912, p. 315.

The literature of the art is rich in discussions of the *physics*¹³ of light production, optical principles, color, etc. Knowledge of these subjects has been distributed rather rapidly through numerous presentations before organizations of men interested in lighting.

In the *measurement of light* notable progress has been made in recent years. The measurement of total flux and light distribution in the laboratory and the measurement of illumination intensity and brightness in lighting installations has been developed and now forms a standard part of illuminating engineering practice.

Beyond the introduction of certain refinements which have promoted accuracy of results, there have been no important developments in the practice of commercial photometry during recent years. Probably the most important development in this field has been the reduction in the size of photometers, which has resulted in making *portable photometers* available for the study of illumination. A recent broadening of the scope of such study has included the measurement of brightness as an important branch of photometry.¹⁴

¹³ *Physics and Chemistry:*

"Transformation of Electric Power into Light," Steinmetz, *Trans. A. I. E. E.*, 1906, p. 789.

"Color Values of Artificial Lamps," Stickney, *Trans. Illg. Eng. Soc.*, 1907, p. 282.

"The Theory of Flame and Incandescent Mantle Luminosity," Fulweiler, *Trans. Illg. Eng. Soc.*, 1909, p. 635.

"Luminous Efficiency," *Trans. Illg. Eng. Soc.*, 1910, p. 113.

"Some Chemistry of Light," Whitney, *General Elec. Review*, 1910, p. 101.

¹⁴ *Photometry:*

"The Integrating Photometer," Matthews, *Trans. A. I. E. E.*, 1902, p. 39.

"Illumination Photometers and Their Use, Millar, *Trans. Illg. Eng. Soc.*, 1907, p. 548.

"A New Universal Photometer," Sharp and Millar, *Elec. World*, 1908, p. 181.

"The Integrating Sphere in Industrial Photometry," Sharp and Millar, *Trans. Illg. Eng. Soc.*, 1908, p. 502.

"Color Measurements of Illuminants," Ives, *Trans. Illg. Eng. Soc.*, 1910, p. 189.

"Illumination Tests," Sharp and Millar, *Trans. Illg. Eng. Soc.*, 1910, p. 391.

"Photometry of Large Light Sources," Stickney and Rose, *Trans. Illg. Eng. Soc.*, 1911, p. 641.

"Photometry at Very Low Intensities," Bell, *Trans. Illg. Eng. Soc.*, 1911, p. 671.

A number of investigators are engaged in the study of the problem of *photometry by non-ocular means*. The thermopile and the photo-electric cell with possibly some alternatives are looked to for assistance in the future. While nothing of commercial practicability has yet demonstrated its value, progress is being made.

The variety of color values of the several important illuminants and the other color values which for scientific purposes must be measured, create a requirement for standards of light of several widely different color values. There is a great need for a series of such standards which shall be authoritative by reason of the auspices under which they have been derived as well as by official designation. A number of laboratories are engaged in the study of this problem of heterochromatic photometry and while concrete results in the establishment of such standards are not available yet, progress must be recorded in that the need for such standards is now definitely established and work is under way, which should result ultimately in meeting this need. Present indications are that a range of *calibrated color screens* offers a most practical solution of this problem.¹⁵

*Standards of light*¹⁶ may be classified as primary, representative, and working standards. Primary standards, or those reproducible from specifications, are at present flame standards, respectively candles, the Hefner lamp and the Pentane lamp. There have been no important developments in the way of primary

¹⁵ *Photometrical Laboratories:*

"Photometrical Laboratories of National Bureau of Standards," Stratton and Rosa, *Trans. A. I. E. E.*, 1905, p. 999.

"A Testing Laboratory in Practical Operation," Sharp, *Trans. A. I. E. E.*, 1905, p. 1051.

"Photometrical Laboratory of the United Gas Improvement Company, Bond, *Trans. Illg. Eng. Soc.*, 1909, p. 619.

"Physical Laboratory of the National Electric Lamp Association," Hyde, *Trans. Illg. Eng. Soc.*, 1909, p. 631.

¹⁶ *Standards of Light:*

"Standards of Light," Nichols, International Electrical Congress, 1904; Steinmetz, *Trans. A. I. E. E.*, 1908, p. 1319.

"Report of the Committee on Nomenclature and Standards, *Trans. Illg. Eng. Soc.*, 1909, p. 520.

"Heterochromatic Photometry and a Primary Standard of Light," Ives, *Trans. Illg. Eng. Soc.*, 1912, p. 376.

standards of light in recent years, although certain means of arriving at a superior primary standard have been suggested and some research work has been done with that end in view. It is generally recognized that none of the existing primary standards of light is entirely satisfactory and that there is need for the development of a new and superior standard. Representative standards have been adopted and the so-called international candle is the official unit of light in England, France, and the United States. It is the result of standardization work of the past few years and the unit is now represented by groups of seasoned, calibrated incandescent electric lamps held at the official laboratories of these three countries. These form a reasonably accurate and safe standard for light of one color value. From them working standards are derived which accurately duplicate the value of the standard lamps and which are now available for general use of all who require them.

A start toward adopting a reasonable system of *units and nomenclature*¹⁷ was made at the Geneva Electrical Congress in 1896. The Committee on Nomenclature and Standards of the Illuminating Engineering Society has been actively engaged in the furthering of this work. That considerable progress has been made will be testified by the several annual reports of the committee to be found in the Transactions of that Society. The subject of nomenclature is especially vexing, and the art is fortunate in having the services of so distinguished a committee to assist in the adoption of sound definitions, symbols, and nomenclature. Pressure is being exerted with a view to the adoption of the metric system and some little progress appears to have been made toward this end.

The principles of physical optics and of magnetic flux underlie many *calculations*¹⁸ made in illuminating practices. Marked im-

¹⁷ *Units and Nomenclature*:

"Reports of the Committee on Nomenclature and Standards, *Trans. Illg. Eng. Soc.*, to date.

"The Concepts and Terminology of Illuminating Engineering." Sharp, *Trans. Illg. Eng. Soc.* 1907, p. 414.

¹⁸ *Calculations*:

"A Rectilinear Graphical Construction of the Spherical Reduction Factor of a Lamp," Kennelly, *Trans. Illg. Eng. Soc.*, 1908, p. 243.

"The Calculation of Illumination by the Flux of Light Method," Cravath and Lansingh, *Trans. Illg. Eng. Soc.*, 1908, p. 518.

petus was given to calculations of illumination by the application of the idea of luminous flux in commercial illumination design. In recent years, the mathematics of the subject have been set forth repeatedly and it may be said that calculations involved in illuminating engineering work are perhaps farther along toward complete development than is any other branch of the subject.

The subject of *costs*¹⁹ is a fundamentally important feature of the science of illumination, and questions of first cost and operating cost, including maintenance and depreciation, must have the careful attention of the practitioner. The literature of this subject is rather meagre, because of the difficulty of generalizing due to the marked influence which local conditions often exercise upon costs and due to the invidious form which cost discussions are likely to take.

So much for the purely engineering aspects of the illuminating art. The engineering features are important, indeed essential, but other aspects are equally so. The subject of *vision* in all its ramifications forms an integral part of the science of illumination, a fact which is being given due recognition. Light must be correct in respect to intensity, direction, diffusion, color, and steadiness; and to the study of these qualities a knowledge of visual processes and methods of perception is essential.²⁰ Shade perception and visual acuity together with color perception have been

"Calculating and Comparing Lights from Various Sources," Hering, *Trans. Illg. Eng. Soc.*, 1908, p. 645.

"The Law of Conservation as Applied to Illumination Calculations," McAllister, *Trans. Illg. Eng. Soc.*, 1911, p. 703.

¹⁹ *Costs*:

"The Analysis of Performance and Cost Data in Illuminating Engineering," Harrison and Magdsich, *Trans. Illg. Eng. Soc.*, 1911, p. 814.

²⁰ *Visual Processes*:

"Effects of Light upon the Eye," Seabrook, *Trans. Illg. Eng. Soc.*, 1908, p. 157.

"Eye-Strain and Artificial Illumination," Krawell, *Trans. Illg. Eng. Soc.*, 1908, p. 212.

"Artificial Illumination from a Physiological Point of View," Standish, *Trans. Illg. Eng. Soc.*, 1908, p. 254.

"Eye-Strain," Pyle, *Trans. Illg. Eng. Soc.*, 1909, p. 447.

"Physiological Effects of Radiation," Steinmetz, *Trans. Illg. Eng. Soc.*, 1909, p. 683.

"The Psychology of Light," Woodworth, *Trans. Illg. Eng. Soc.*, 1911, p. 437.

studied and discussed to an extent which begins to make known some of the more important facts pertaining to vision.

In this connection also the subject of *contrast* may be considered. A knowledge of the behavior of the human eye under various conditions of contrast is all essential to the science of illumination. Therefore the study of reflection and absorption of light and of brightness of surfaces is a prominent feature of the most recent advance in the science of illumination. Glare both from light source and from reflecting surfaces is largely a question of contrast and its suppression in order to promote ocular welfare is one of the principal aims of the lighting practitioner to-day.²¹ Excessive brightness means excessive contrast with surrounding objects.²² Sometimes a light source, which is so bright as to occasion discomfort amid dark surroundings, becomes innocuous when amid bright surroundings. The general recognition of the need for contrast limitation has been effective in reducing contrast in the more recent installations.²³

Glare is intimately connected with diffusion of light. It is a subject to which a great deal of study has been given within the

²¹ *Methods of Perception:*

"Some Physiological Factors in Illumination and Photometry," Bell, *Trans. Illg. Eng. Soc.*, June, 1906, p. 3.

"Allowable Amplitudes and Frequencies of Voltage Fluctuations in Incandescent Lamp Work," Ives, *Trans. Illg. Eng. Soc.*, 1909, p. 709.

"Physiological Points Bearing on Glare," Cobb, *Trans. Illg. Eng. Soc.*, 1911, p. 153.

"Notes on Spectral Character of Light upon the Effectiveness of Vision," Luckiesch, *Trans. Illg. Eng. Soc.*, 1912, p. 135.

²² *Brightness:*

"Intrinsic Brightness of Lighting Sources," Woodwell, *Trans. Illg. Eng. Soc.*, 1908, p. 573.

"The Measurement of Brightness and its Significance," Ives, *Trans. Illg. Eng. Soc.*, Volume 9, No. 3.

²³ *Light Absorption and Reflection Coefficients:*

"Coefficients of Diffuse Reflection," Bell, *Trans. Illg. Eng. Soc.*, 1907, p. 653.

"Some experiments on Reflection from Ceilings, Walls and Floor," Lansingh and Rolph, *Trans. Illg. Eng. Soc.*, 1908, p. 584.

"Effect of the Variation of the Incident Angle on the Coefficient of Diffuse Reflection," Gilpin, *Trans. Illg. Eng. Soc.*, 1910, p. 854.

"Reflection Coefficients," Bauder, *Trans. Illg. Eng. Soc.*, 1911, p. 85.

"Some Reflecting Properties of Painted Interior Walls," Jordan, *Trans. Illg. Eng. Soc.*, 1912, p. 529.

last few years. In a paper before this Institute, Sweet presented the results of some laboratory experiments on the effect of glare due to the presence of a light source within the field of vision. While the conditions which he employed were extreme and the effect was exaggerated beyond that met in practice, yet the consequences experienced in ordinary installations differ from those found in his experiments only in degree. Glare due to exposed light sources means diminished seeing ability, discomfort and possible injury to the eyes. Another effect also known as glare is that attending specular reflection from polished surfaces. This is a subject which has received especial attention during recent years. Glare of this kind is again a matter of excessive contrast. One views the imperfectly reflected image of a light source upon the page of a book, brightness of the image being far in excess of the immediate surroundings and the general surroundings. The same means which are effective in reducing contrasts between the light source and its surroundings are naturally effective in reducing the contrast between the reflected image of the light source and its surroundings. Thus in avoiding glare due to exposed light sources, glare due to specular reflection is likewise avoided.²⁴

The engineering aspects, together with those aspects which pertain to vision, in large part constitute the science of illumination. *Æsthetics* as comprehended in the principles of design, ornamentation, and decoration may, in a sense, be grouped under the science of illumination, and to the extent that it is so considered, it is essentially important. Obviously, however, *æsthetics* is so much a matter of artistic feeling that the entire subject cannot be classed under this heading.²⁵

A growing appreciation of the artistic possibilities of lighting

²⁴ *Contrast, Glare, etc.:*

"Physiological Points Bearing on Glare," Cobb, *Trans. Illg. Eng. Soc.*, 1911, p. 153.

"Artificial Illumination as a Factor in the Production of Ocular Discomfort," Black, *Trans. Illg. Eng. Soc.*, 1911, p. 166.

"The Effectiveness of Light as Influenced by Systems and Surroundings," Cravath, *Trans. Illg. Eng. Soc.*, 1911, p. 782.

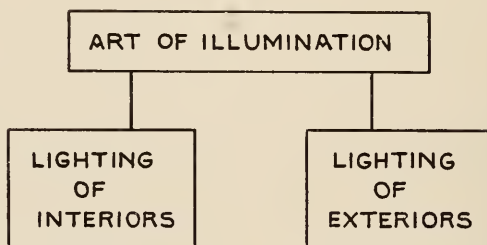
²⁵ *Æsthetics, Architectural Principles, etc.:*

"Electric Light as Related to Architecture," Walker, *Trans. Illg. Eng. Soc.*, 1907, p. 596.

"The Relation of Architectural Principles to Illuminating Engineering," Jones, *Trans. Illg. Eng. Soc.*, 1908, p. 9.

and the growing demand for artistic execution in lighting design are gradually introducing more pleasing features, glassware, and lamps. It is one of the gratifying and encouraging features of the situation that there is nothing inconsistent in the requirements of good illumination whether they be requirements of efficiency, ocular hygiene, or æsthetics. It appears that in promoting the one, natural impetus is given to one or both of the others. The more efficient light sources are likely to be more brilliant and to carry with them the need for concealment from view. In meeting this need, design along the lines of least resistance results in dif-

FIG. II.



fused light from larger areas, forming secondary sources which do not disturb ocular comfort. In the design of such systems of lighting, opportunities for the creation of pleasing and artistic effects thrust themselves upon the designer in a manner which was never encountered when less efficient illuminants of lower brilliancy were placed in rooms without adequate concealment.

The *art* of illumination²⁶ is the lighting of interiors and of

"Modern Methods of Illumination from the Architectural Standpoint," Castor, *Trans. Illg. Eng. Soc.*, 1908, p. 271.

"The Relation of Illuminating Engineering to Architecture from the Illuminating Engineering Standpoint," Elliot, *Trans. Illg. Eng. Soc.*, 1908, p. 280.

"Architecture and Illumination," Perrot, *Trans. Illg. Eng. Soc.*, 1908, p. 619.

"Illumination and Architecture," Furber, *Trans. Illg. Eng. Soc.* 1910, p. 822.

"The Architect and Illuminating Engineering," Trimble, *Trans. Illg. Eng. Soc.*, 1912, p. 51.

²⁶ ART OF ILLUMINATION.

Decorative Aspects:

"Light and Color in Decoration," Hunter, *Trans. Illg. Eng. Soc.*, 1908, p. 190.

exteriors. The specialist applies daylight and artificial illuminants employing lighting auxiliaries and fixtures conforming to correct engineering, ocular and æsthetic principles in the lighting of interiors and exteriors. The art of illumination may be improved only as better materials of illumination are made available and as the science of illumination is advanced. In the lighting of interiors, more or less in accordance with established illuminating principles, much experience has been gained and recorded in recent years and considerable advance in practice has resulted. In the Transactions of the Illuminating Engineering Society alone there are more than 50 papers dealing with the illumination of interiors, many of them containing definite photometric data on the results obtained. This experience covers a wide variety of installations ranging from the illumination of churches and theatres through illumination of stores and factories to the simpler problems of lighting garages and stable.

That remarkable advances have been made in the *lighting of interiors* during the last five years will probably not be denied. Better materials of illumination are available and knowledge of correct principles of illumination has increased rapidly. Experiments in the design of lighting equipment and its installation have

"The Relationship of Decoration to the Illuminating Engineering Practice," Clifford, *Trans. Illg. Eng. Soc.*, 1910, p. 179.

Church Lighting:

"Church Lighting," Perrot, *Trans. Illg. Eng. Soc.*, 1908, p. 369.

"Indirect Lighting in Auditoriums," Wheeler, *Trans. Illg. Eng. Soc.*, 1912, p. 163.

"Church Lighting," Ely, *Trans. Illg. Eng. Soc.*, 1912, p. 613.

Lighting of Auditoriums and Theatres:

"The Illumination of Hammerstein's Philadelphia Opera House," Spillman, *Trans. Illg. Eng. Soc.*, 1909, p. 385.

"Theatre Illumination," Vaughn and Cook, *Trans. Illg. Eng. Soc.*, 1911, p. 961.

Office Lighting:

"The Illumination of the Building of the Edison Electric Illuminating Company of Boston," Bell, Marks and Ryan, *Trans. Illg. Eng. Soc.*, 1907, p. 603.

"Illumination of the Engineering Societies' Building, New York," Knox, *Trans. Illg. Eng. Soc.*, 1907, p. 445.

"Illumination of the Office Building of the Philadelphia Electric Company," Bartlett, *Trans. Illg. Eng. Soc.*, 1908, p. 555.

"Indirect Illumination of the General Offices of a Large Company," Aldrich and Mailia, *Trans. Illg. Eng. Soc.*, 1914, p. 103.

sometimes failed to give satisfaction, but usually have given some lesson which has added to the total experience in lighting practice. Developments which in themselves have not achieved permanent success have in some cases been stimulative, and have promoted the best development of lighting practice.

In the *lighting of exteriors* there has been some advance also. Street lighting is so largely dependent upon municipal appropriations that its development is sometimes hampered unduly by lack of funds. Merchants' associations have found in street lighting a means of promoting trade, and have had recourse to display street lighting to supplement the lighting provided by the city. Thus, tungsten cluster lighting has been installed in many cities, particularly the smaller cities of the country, with a very beneficial effect upon street lighting as a whole. More recently a competitive form of illumination, known as the "Ornamental Arc Lamp System," in which an inverted arc lamp is employed, has commanded much attention and is experiencing notable growth. General civic street lighting is improving slowly, the average standard of intensities being increased, and somewhat better de-

"Some Engineering Features of Office Building Lighting," Edwards and Harris, *Trans. Illg. Eng. Soc.*, 1914, p. 164.

School Lighting:

"Schoolhouse Illumination," Hatch, *Trans. Illg. Eng. Soc.*, 1907, p. 359.

"Public Schoolroom Lighting," Knight and Marshall, *Trans. Illg. Eng. Soc.*, 1910, p. 553.

Library Lighting:

"Design of the Illumination of the New York City Carnegie Libraries," Marks, *Trans. Illg. Eng. Soc.*, 1908, p. 538.

Store Lighting:

"The Lighting of a Large Store," Law and Marshall, *Trans. Illg. Eng. Soc.*, 1911, p. 186.

"Department Store Lighting," Shalling, *Trans. Illg. Eng. Soc.*, 1913, p. 17.

"Distinctive Store Lighting," Law and Powell, *Trans. Illg. Eng. Soc.*, 1913, p. 515.

"Present Practice in Small Store Lighting," Law and Powell, *Trans. Illg. Eng. Soc.*, 1912, p. 435.

Factory Lighting:

"Factory Lighting," Marks, *Trans. Illg. Eng. Soc.*, 1909, p. 805.

"Mill Lighting," Stickney, *Trans. Illg. Eng. Soc.*, 1911, p. 478.

"Factory Lighting," Flexner and Dicker, *Trans. Illg. Eng. Soc.*, 1913, p. 470.

sign of the illuminants and systems being noted in the more recent installations.

There is some little development in the way of lighting exteriors of buildings. Outline lighting of expositions was first carried out in a notable manner at the Columbian Exposition in 1893, attaining perhaps its highest development at the Pan-American Exposition in Buffalo in 1901. The Jamestown Exposition struck a new note in lighting building exteriors, and in the Panama-Pacific International Exposition in San Francisco, 1915, we are promised a fuller development of the lighting of buildings by concealed sources.

These occasional remarkable installations are, of course, few in number. There is no general tendency to light the exteriors of buildings, though a few creditable attempts have been made in this direction.

PROGRESS IN ILLUMINATION.

Having reviewed briefly the recent developments in the field of illumination, allow me to direct your attention briefly to the subject of progress and to the forces which have been responsible for improvements in the past and to which we must look for further development.

The illumination which is provided depends not only upon the

Show Window Lighting:

"Show Window Lighting," Henninger, *Trans. Illg. Eng. Soc.*, 1912, p. 178.

"Show Window Lighting," Wheeler, *Trans. Illg. Eng. Soc.*, 1913, p. 555.

Residence Lighting:

"Residence Lighting," Cravath, *Trans. Illg. Eng. Soc.*, 1906, p. 164.

"Some Home Experiments in Illumination from Large Area Light Sources," Ives, *Trans. Illg. Eng. Soc.*, 1913, p. 229.

"The Lighting of a Simple Home," Powell, *Trans. Illg. Eng. Soc.*, 1914, p. 45.

Passenger Car Lighting:

"The Lighting of Railway Cars," Hulse, *Trans. Illg. Eng. Soc.*, 1910, p. 75.

"Illumination of Passengers Cars," Minick, *Trans. Illg. Eng. Soc.*, 1913, p. 214.

"Modern Practice in Street Railway Illumination," Hibben, *Trans. Illg. Eng. Soc.*, 1913, p. 589.

"The Illumination of Street Railway Cars," Porter and Staley, *Trans. Illg. Eng. Soc.*, 1914, p. 25.

status of the art but also upon the degree to which practice conforms with the art. It has been stated that the art of illumination is improved as the materials of illumination are bettered and as the science of illumination is advanced. It may now be added that illuminating practice is improved as individuals, manufacturers in the lighting field, contractors in the lighting field, and lighting companies better their practice. It is to be regretted that in a review of recent progress in the field of illumination, note must be taken of the fact that illuminating practice has not advanced as rapidly as the development of the materials of illumination and the advance of the science of illumination would appear to make possible. The art of illumination has made rapid strides. Manufacturers, contractors, and lighting companies have improved their practice in many instances. Unfortunately, however, their influence is largely confined to new installations in stores and to some large manufacturing establishments. Where the commercial incentive is clearly discernible, old installations have been brought up to date very generally. With these exceptions the older installations, dating back ten years or more, compare unfavorably with the best that the art affords.

General:

- "Indirect Illumination," Curtis and Morgan, *Trans. Illg. Eng. Soc.*, 1908, p. 740.
- "Daylight Illumination," Marsh, *Trans. Illg. Eng. Soc.*, 1908, p. 224.
- "Symposium on Indirect, Semi-Indirect and Direct Lighting," Rolph, Henninger and Hibben, *Trans. Illg. Eng. Soc.*, 1912, p. 234.

Street Lighting:

- "A Method of Street Lighting by Incandescent Lamps," Underwood and Lansingh, *Trans. Illg. Eng. Soc.*, 1906, p. 115.
- "Lighting of Streets by the Incandescent Mantle Burner System," Westermaier, *Trans. Illg. Eng. Soc.*, 1906, p. 122.
- "Street Lighting," Bell, *Trans. Illg. Eng. Soc.*, 1908, p. 400.
- "Street Lighting by Tungsten Lamps," Rhodes, *Trans. Illg. Eng. Soc.*, 1909, p. 54.
- "Some Neglected Considerations Pertaining to Street Illumination," Millar, *Trans. Illg. Eng. Soc.*, 1910, p. 653.
- "Street Lighting with Ornamental Luminous Arc Lamps," Halvorson, *Trans. Illg. Eng. Soc.*, 1913, p. 88.

Lighting of Building Exteriors:

- "The Lighting of the Buffalo General Electric Company's Building," Ryan, *Trans. Illg. Eng. Soc.*, 1912, p. 597.

Broadly speaking, a review of recent developments throughout the entire field must prove encouraging to all who are interested in the subject of illumination, with the single exception that means

FIG. 12.



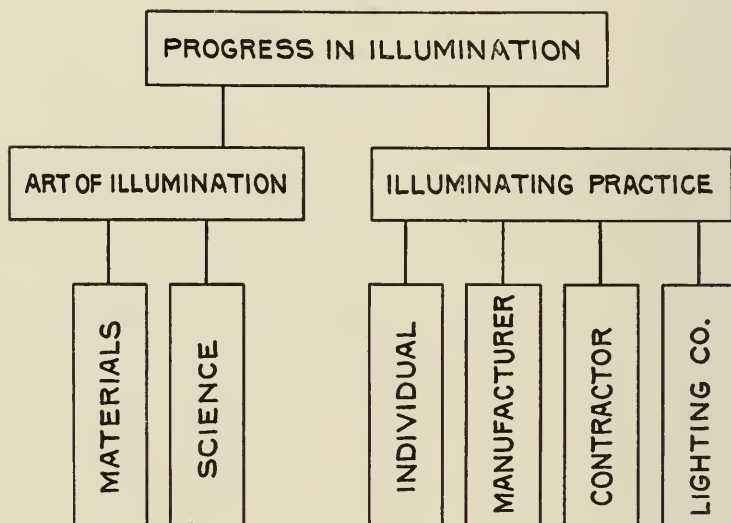
Building of the Denver Gas and Electric Company as lighted at night.

have not yet been devised for bringing old installations up to date and into conformity with present day knowledge of lighting principles.

FORCES TENDING FOR BETTERMENT IN THE ILLUMINATION FIELD.

The progress of the past few years in the field of illumination is largely traceable to definite sources, and consideration of these sources warrants the belief that recent progress may be taken as an earnest of further progress to be anticipated for the near future. The Illuminating Engineering Society is a forum for the discussion of lighting questions. It fosters study in the field, collects in its transactions most of the important literature of the art, and seeks to disseminate information regarding illumination. The Johns Hopkins University Illuminating Engineering Society

FIG. 13.



lecture course on illuminating engineering laid the groundwork for educational courses devoted to the subject, and a Committee on Education of the Illuminating Engineering Society is now seeking to further pedagogic interest and activity along this line. The national associations of electric companies and of gas companies are doing educational work in this field. The Illuminating Engineering Society is conducting a campaign of popular education. All of these efforts have made for progress, and may be looked to for future progress. The manufacturers of illuminants and accessories in this country are remarkably progressive. Their researches and investigations and educational work are bringing large results throughout the entire field. Lighting companies are awakening to the importance of illumination. While perhaps the power business in both the electric and gas industries

is assuming greater importance than the lighting business, yet it is the lighting business upon which the reputation of the company for furnishing good service or poor service is most likely to depend, and which offers far more opportunity for cultivating public good-will through acceptable service than does the power business. Most large electric and gas companies now have on their staff one or more illuminating engineers, and are devoting more attention than formerly to the subject of good illumination.

FIG. 14.

ADVANCES IN SCIENCE OF ILLUMINATION DURING RECENT YEARS

CONCEALMENT OF BRILLIANT LIGHT SOURCES.

KNOWLEDGE OF QUALITIES OF ILLUMINANTS AND AUXILIARIES.

CONCEPT OF LIGHT FLUX.

COLLECTION OF PHOTOMETRIC ILLUMINATION DATA.

AVOIDANCE OF EXTREMES IN CONTRAST.

APPRECIATION OF ARTISTIC REQUIREMENTS.

FIRST GLIMMERINGS OF RECOGNITION OF PSYCHOLOGICAL REQUIREMENTS. (1914.)

IMPORTANCE OF THE SUBJECT.

In conclusion, allow me to enter a plea for more general attention to the subject of illumination. It is one of transcending importance whether viewed from a humanitarian or a commercial standpoint. Some estimates for the year 1913 of its commercial importance in this country have recently been published.²⁷ According to these the manufacturer's sales of materials employed directly for illumination in the electric lighting industry alone aggregated \$65,000,000, while the sales of machinery involved in the generation of electricity for lighting purposes aggregated perhaps half of this amount. The revenue of central stations derived from the electric lighting business is estimated as exceeding \$300,000,000. These figures suggest in some measure the importance of the electric lighting industry and of course are in need of supplement by corresponding figures representative of the gas lighting industry and of the miscellaneous lighting business of the country. But if all such figures were available, they would only begin to suggest the commercial importance of arti-

²⁷ Editorial, *Lighting Journal*, January, 1914.

ficial illumination to the country. Who shall attempt to estimate the colossal additions to the wealth of the nation which it makes possible through extending the hours of industry?

The importance of artificial illumination in another sense is difficult to overestimate.

“*Health* in the home is dependent upon proper sanitation. ‘Cleanliness is next to Godliness’; without proper light, cleanliness is next to impossible! Adequate illumination promotes cleanliness.

“Ophthalmologists tell us that inadequate or otherwise improper illumination occasions eye-strain which often results in headache and other nervous disorders. These, if prolonged, sooner or later undermine general health. So, good illumination affects general health by promoting sanitation and avoiding nervous strain.

“Good illumination has a more direct bearing upon the health of the eyes. If the eyes are closely employed upon detailed work, as in sewing or reading, under conditions of illumination which are improper, the eyes are fatigued, and if the occupation is continued, in spite of the fatigue, vision is impaired at least temporarily, and possibly is injured permanently. As compared with our forefathers we are distinctly a nocturnal people. We use our eyes a greater number of hours per day. Oculists’ records testify, and the prevalence of eye-glasses evidences, the deleterious effects upon the vision of the people as a whole. Who shall say what part of the prevalence of impaired vision is attributable to improper illumination, that is to say, to the misuse of light?

“Physiologists tell us that the human eye is naturally adapted for distant vision; that when focused upon nearby objects, as in most of the work in which it is applied in our modern life, the muscles are contracted and the focal mechanism of the eye is subjected to strain. They tell us also that, just as children are physically, intellectually, and morally more susceptible and pliant than adults, so the visual organs of children are delicate and especially liable to injury if used under adverse conditions. In modern life children are called upon for a large amount of home-work in connection with the school systems. This involves application of the eyes in exacting near vision to which they are not naturally adapted, and at a time of life in which they are peculiarly liable to injury. When to these untoward conditions there is added that

of poor illumination, is it any wonder that we are becoming a bespectacled race? Of these conditions which operate against ocular welfare some may be beyond our control, but that of poor illumination is a menace for the existence of which there is no excuse, since the remedy is understood and is available to all.

“Light has a marked bearing upon the *usefulness* of our lives. Artificial light extends the hours in which we may labor. It makes possible intellectual improvement; it permits added achievement; it makes actual life of fifty years equivalent to a much longer life in the period antedating the perfection of our modern light sources. Yet, though these statements are in general correct, it remains true that the precise measure of added usefulness which artificial light makes possible depends upon the merits of the illumination. With good illumination one may labor to better effect, may produce more largely, and the product will be more nearly perfect than with poor illumination. These facts may be applied to the industries and to the arts, to manufacture, to the pursuit of knowledge, or to the development of artistic talent.

“Artificial light is an important factor in promoting *happiness*. In extending the hours of activity beyond those which are ordinarily devoted to the duties of life, it affords opportunity for the pursuit of pleasure. Light reveals the beauties of nature and of art, whether it be sculpture, painting, or architecture. It is particularly important in the home where so much effort is expended for the comfort and pleasure of the family. Few homes are so humble but that some effort is made to render them attractive. The home usually reflects in its decorations the personality of the home-maker, and, within the limits of the tastes and means of the family, attempt is generally made to render it homelike and charming. Much of the beauty and charm are lost in the evening if the rooms are not properly illuminated.”²⁸

Considering the immense importance of artificial illumination as a factor in the progress of the country, every advance in the science of illumination, every improvement in the materials of illumination, and all progress in the art has a special significance—even a minor improvement in materials or in the science may have a large general influence if embodied in standard practice. It is

²⁸ Mrs. P. S. Millar, Froebel Society, Brooklyn, November, 1913.

therefore of interest to consider the improvements which have been brought about in the recent past, the discrepancy between some of the present practice and the best that the art affords, and the opportunity which each one of us has to influence one or more lighting installations for good. Considering the importance of the subject and the progress being made, it is a gratifying task to undertake to report upon recent developments, even though such report is recognized as being but little more than suggestive as to the facts.

Influence of the Casting Process on Wrought Non-ferrous Materials. ANON. (*Amer. Mach.*, xli, No. 8, 329.)—In a discussion before the American Society for Testing Materials it was pointed out that the surface of molten brass becomes instantly covered with a thick film of oxide on exposure to the air, and this oxide must be prevented from becoming incorporated in the solidified metal. Two instances will illustrate the importance of proper casting. Ingot copper of the finest character, as received from the refining furnace, is neither very ductile nor malleable when cold, but when properly melted and cast from a crucible it becomes highly so. A properly cast billet should show no pipe at the upper end, but when improperly cast a considerable pipe may occur. The casting process, when properly performed, leaves the bar, billet, or ingot free from blow-holes, gas cavities, or dirt, and from surface imperfections.

Luminosity of Neon Tubes as a Function of Their Diameter. G. CLAUDE. (*Comptes Rendus*, clviii, 692.)—The author has verified the law of variation of fall of potential as a function of the diameter of neon tubes along the luminous column of those tubes. The object of the present experiments is to ascertain the consequences of this law from the point of view of luminosity. The table of results shows that the lighting power, with equal current densities, does not increase in proportion to the sections, but barely as the diameters. Now, if the current increases as the square of the diameter, the fall of potential in the column decreases inversely as the diameter, so that taken altogether the electric power absorbed in the column increases only as the diameter, and, as the lighting power increases approximately according to the same law, it follows that the quantity of light produced is connected with the energy expended. When considering the output of the luminous column only, both very large and very small tubes are at a disadvantage. Quite satisfactory results, however, can be obtained with tubes of diameters 40 mm. to 10 mm. The lighting power furnished by a tube of given length diminishing very nearly as its diameter without the output suffering, it is therefore possible to arrange a very economic form of lighting.

THE QUALITY OF THE TWENTY-FOUR-INCH OBJECTIVE OF THE SPROUL TELESCOPE, AS DETERMINED BY HARTMANN TESTS.*

BY

JOHN A. MILLER,

Professor of Mathematics and Astronomy, Swarthmore College, Swarthmore, Pa.,

AND

ROSS W. MARRIOTT,

Assistant Professor of Mathematics, Swarthmore College, Swarthmore, Pa.

THE telescope for the Sproul Observatory was completed in the summer of 1911 and mounted in the observatory the following December. The objective of the telescope, which was built by the John A. Brashear Co., Ltd., is 24 inches in diameter, and has a focal length of approximately 433 inches. The lens was made from a Crown disc furnished by the Parra-Mantois firm, of Paris, and a flint disc furnished by Schott and Genossen, of Jena. In February of 1912, the writers began a test of the lens, using the method of extra-focal images devised by Hartmann,¹ and applied by him, and also by others, to numerous objectives, the most notable of which is perhaps the test of the 80 cm. objective of the Potsdam refractor. The method of making this test has been frequently described² and the reader will recall its essential features. The objective is covered with an opaque screen in which a suitable number of circular openings have been made, through which light from a star (or other source) can pass. These openings serve to isolate such parts of the lens as the observer chooses to test.

If the focus of the telescope is at F^1 , and if the bundles of rays that come from a pair of holes intersect a plane P_1 , within the focus, at the points B and C respectively, one can measure $BC = e_1$ (say). If also the bundles of rays that come from the

* Communicated by Professor Miller.

¹ Hartmann: *Zeitschrift für Instrumentenkunde*, vol. 24.

Plaskett: *Astrophysical Journal*, vol. 25.

Fox: *Astrophysical Journal*, vol. 27.

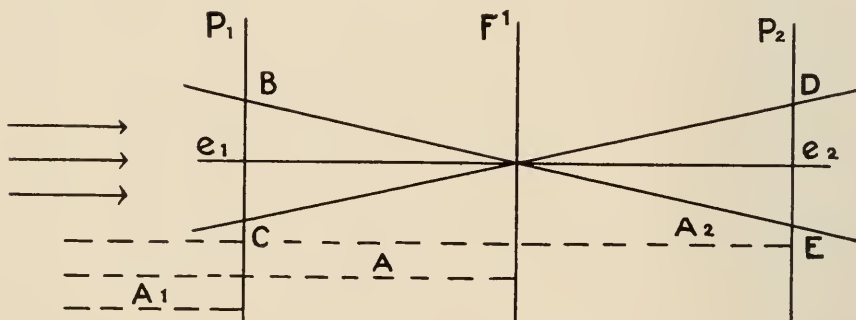
² Opera cited: Pub. des Astrophysikalischen Obs. zu Potsdam, Nr. 46.

same pair of holes intersect a plane P_2 , without the focus at the points D and E , one can measure the distance $DE = e_2$ (say). If, further, he knows the distance between P_1 and P_2 , he can by solving similar triangles calculate the distance of F , the intersection of the beams from any pair of openings, diametrically situated on the same zone, from the plane P_2 by the formula—

$$A_2 - A = \frac{e_2}{e_1 + e_2} (A_2 - A_1) \quad (1)$$

where A_1 , A_2 and A are respectively the distances of P_1 and P_2 and F from the optical centre of the objective. This formula, including the notation, is practically the same as the one which was deduced by Hartmann, which we modified slightly in order that we might compute $A_2 - A$, the distance of F from the plane P_2 , instead of its distance from the objective as Hartmann did.

FIG. 1.



The distances e_1 and e_2 may be measured with a micrometer, or, having let the rays fall on a photographic plate, the distance between the images may be measured on the plate. The latter is the more convenient way. Now, the quantity $A - A_2$ will depend chiefly upon the objective, but it will be influenced by the color of light being used, and also upon the character of the plate. One might, as Hartmann did in many of his tests, render the rays of light monochromatic by using the spectroscop. This we did not do, our object being rather to determine the quality of the objective under the same circumstances that the telescope is being used. The telescope at present is used chiefly for making photographs for the determination of stellar parallax. The objective is corrected for visual rays, and in order to use the flattest part of the field we photograph through a ray filter, made for us by

Wallace, which is opaque to the violet end of the spectrum and nearly so for the red end. The filter is made of optical glass and is placed very close to the plate. We use Cramer's Instantaneous Isochromatic Plates. The photographs for making the extra-focal test of the objective, which is discussed in what follows, were made in this way.

EARLIER TESTS.

Our first attempt was made on February 22, 1912. Six exposures were made on Capella, when it was near the meridian, through a screen containing 44 circular holes, each 33 mm. in diameter, so arranged as to cover nine zones of the objective. Six sets of plates were made, measured, and reduced. Hartmann's characteristic quantity ³ T , which measures the quality of a lens, calculated from these plates was small ($= .27$). But the measures showed certain discrepancies among the focal distances of different parts and zones of the lens that, although not excessive, were absent when the objective was in the optical room.

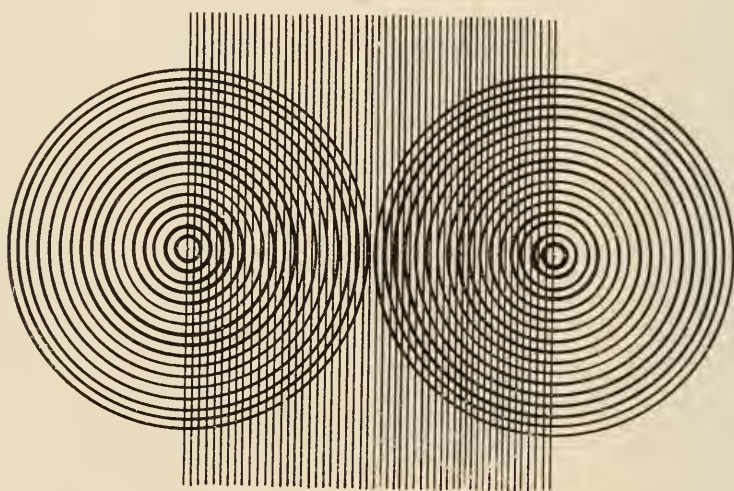
The objective is prevented from sliding in its cell by the pressure of a spring on one side of it, and Mr. McDowell, of the Brashear Company, suspected that these discrepancies might be due to this pressure. Later, June 5, 1912, we reduced this pressure and repeated the extra focal test, using Arcturus when it was near the meridian. The screen used in this test contained 78 circular openings each 25 mm. in diameter, so arranged that we could investigate ten zones. We found that, although the exposures on Capella were made when the temperature was low and with the telescope east of the pier, while those on Arcturus were made when the temperature was high and the telescope west of the pier, those parts of the objective that showed short (or long) focus in one of the tests showed the focus short (or long) in the other test also, though in the second case they were numerically smaller.

The extra-focal images, at least, are not good, and the smaller the openings the worse they are. But the larger the opening the smaller the number that can be put into the screen, and the less exhaustive the test is. Moreover, the plates must be put far enough out of focus so that images in the pattern, resulting from

³ *Zeitschrift für Instrumentenkunde*, Bd. 24.

intercepting the beams from the separate holes, may not overlap each other. Having these natural precautions in mind, it so happened that when we made the first screen for photographing Capella we chose values for the radius of the circular opening and the distance of the plates from the focus in such a way that a most peculiar condition resulted. Between each two adjacent images on a diameter there was found a spurious image elongated in a direction perpendicular to the radius upon which the openings lay. We afterwards increased the radius of the openings and changed the extra-focal differences somewhat, thereby eliminating these spurious images entirely.

FIG. 2.



However, we were curious to know the relation that must exist between these various magnitudes in order that the spurious images might appear, or rather would not appear. Miss Marion R. Stearne, then a Senior in Swarthmore College, investigated the matter and found that these spurious images are interference effects and deduced a formula by which one might construct a screen, giving extra-focal patterns from which these spurious images are absent. Miss Stearne found that these spurious images were due to systems of circular maxima and minima (those resulting from the diffraction pattern of a single aperture) which are crossed by alternate dark and bright bands, which are arcs of hyperbolæ and which differ very little from straight lines which are perpendicular to the line joining the centres of the images of the star from two adjacent apertures as in the figure

—and are due to interference of the beams coming from the two apertures.

Below follows a *résumé* of Miss Stearne's work:

Let i = intensity of the illumination at any point of a plane by light coming through a single circular aperture.

Let I = intensity of illumination of any point of a plane by light coming through two circular apertures, of equal radii.

c = distance between the centres of the apertures.

ϕ = angle of diffraction.

λ = wave-length of light.

r = radius of the apertures.

It is proved in physical optics that if light comes through a single circular aperture, there results a system of concentric circular maxima and minima of intensity of illumination of a plane. The minima of intensity are all zero. The centres of these circular maxima and minima coincide with the centre of the images, and their angular radii, θ , as seen from the optical centre is (m an integer):

$$\theta = \frac{m\lambda}{r}$$

Let us call these the first system of maxima and minima. It is further proved in physical optics that

$$I = 4i \sin^2 \left(\frac{\pi c}{\lambda} \sin \phi \right).$$

If we now fix our attention on a particular maximum of the first system, then i is constant.

If we put $\frac{dI}{d\phi} = 0$, one finds either

$$\cos \phi = 0$$

or

$$\sin \left(\frac{2\pi c}{\lambda} \sin \phi \right) = 0.$$

And since $\frac{\pi}{2}$ is not an admissible value,

$$\sin \phi = \frac{n\lambda}{2c}.$$

When n is odd, $\frac{d^2I}{d\phi^2}$ is negative, and hence for these values I is a maximum.

When n is even, $\frac{d^2I}{d\phi^2}$ is positive and hence for these values I is a minimum. That is, there results a system of alternately dark and bright bands, which are straight lines perpendicular

to the line joining the centres of the apertures. Accordingly, in addition to the precautions mentioned on page 467 it becomes necessary to eliminate these bands that arise from the interference of the beams that come from two adjacent apertures. Since ϕ is small we may put $\sin \phi = \phi = \frac{n\lambda}{2c}$; that is, the distances of these bands from a line perpendicular to one joining the centres of the images are inversely proportional to the distance between the centres of the apertures, while the radii of the first system of circular apertures vary inversely as the radius r of the apertures. We can therefore eliminate these to any degree of approximation either by properly choosing r and c , or by placing the plates far enough from the focus; the latter method has the objection that the far-out-of-focus images are not measurable.

Let θ = the angular radius of the n th maximum of the circular system, and if we put,

$$m_n = \frac{\pi r \sin \theta}{\lambda} = \frac{\pi r \theta}{\lambda}$$

$$\theta = \frac{m_n \lambda}{\pi r}.$$

It can be shown from the geometric properties of image formation that the interference from the beams through two adjacent apertures can be eliminated to the $\left(\frac{n}{2}\right)$ th band, if we put

$$\frac{m_n \lambda}{\pi r} > \frac{2n\lambda}{2c}.$$

Also if—

f = focal length of the objective,

x = distance of the plate from the focal plane,

h = distance from the axis of the objective to the extra-focal image.

Then,

$$\frac{f-x}{h} \leq \frac{2c}{n\lambda} = \frac{r}{\lambda};$$

$$\frac{x}{h} = \frac{2f}{c}$$

$$\frac{f}{h} \leq \frac{r}{\lambda} + \frac{2f}{c}$$

$$x = \frac{2fh}{c}$$

That is, if one is testing an objective of focal length, f , having chosen two of the quantities r , n , c or x , arbitrarily, he may determine the remaining ones from the preceding equations and inequalities, so that the spurious images mentioned above are absent.

THE FINAL TEST.

In 1913, we decided to repeat the Hartmann test of the objective, after having again reduced the pressure of the spring referred to on page 467. We constructed screens meeting approximately the foregoing specifications, choosing $n=9$, and $r=18$ mm.; hence since for our objective $f=11,010$ mm. approximately, $c=81$ mm., and $x=90$ mm. approximately.

Because the photographic eyepiece of the telescope made it convenient to do so, instead of $x=90$ mm., we chose to separate the planes P_1 and P_2 by 200.5 mm. The resulting images were the best we had obtained.

In order to cover the lens very completely, we decided to use three screens.

Screen No. 1. Contained 32 holes, arranged on 8 zones; the radii of the zones on this screen were 2, 5, 6.5, 8, 8.75, 9.5, 10.25, and 11 inches.

Screen No. 2. Contained 36 holes, arranged on 9 zones; the radii of these zones were 2.25, 4.25, 5.25, 7.25, 8.375, 9.175, 9.875, 10.625, and 11.375 inches.

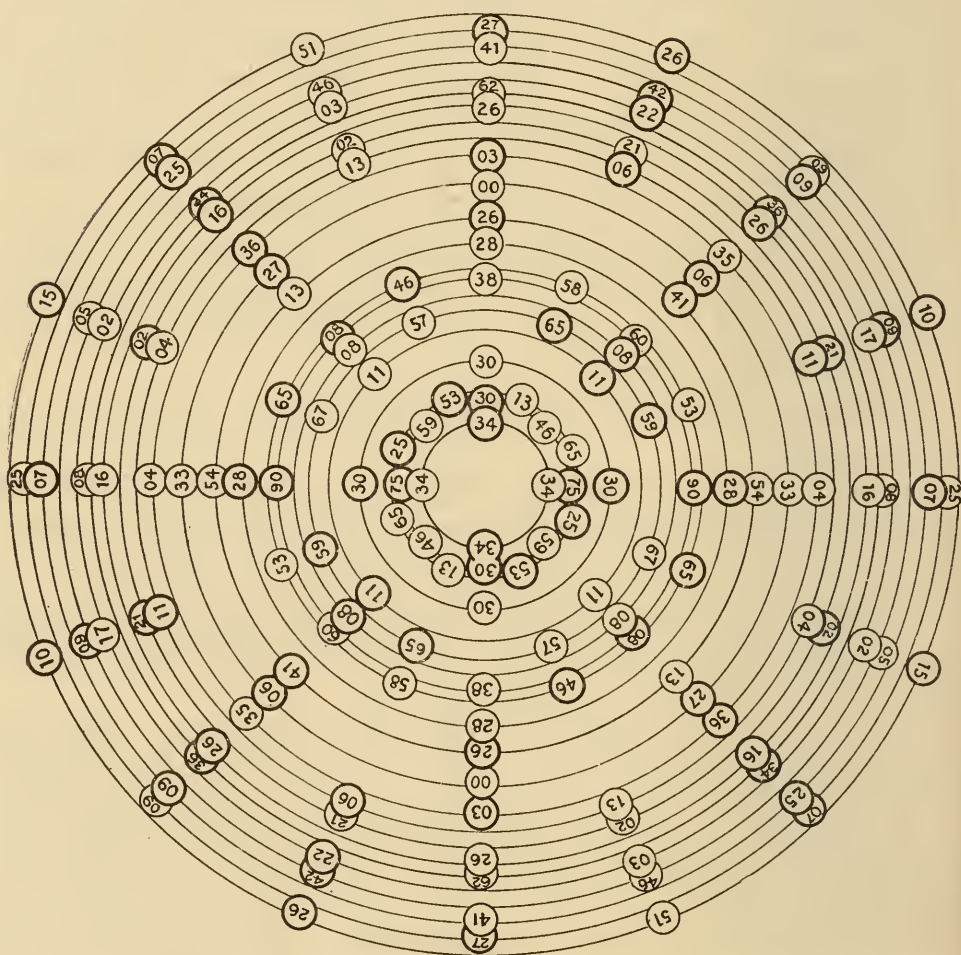
Screen No. 3. Contained 14 holes, arranged on 7 zones; the radii of these zones were 1.5, 3, 3.75, 4.5, 5.875, and 7.625 inches.

On January 9, 1913, Capella, when near the meridian, was photographed through each of these screens, in the following manner:

Each screen was used in two positions. Screen No. 1 was set with a given diameter parallel to the equator, and five exposures made. It was then rotated through 45 degrees about an axis through the centre of the lens perpendicular to the plane of the screen and five additional exposures made on another plate. Screen No. 1 was then removed and Screen No. 2 placed over the lens, and, five exposures through it having been made, it was turned 45 degrees and five additional exposures made on another plate. Screen No. 2 was then removed and Screen No. 3 put in its place, and, five exposures having been made, it was

turned through 90 degrees. Integrating these results, this was equivalent to photographing through a single screen containing 164 holes, arranged on 24 zones. There were 8 holes on each of 17 zones and 4 holes on each of 7 zones. These holes were distributed on diameters making angles of $22\frac{1}{2}$ degrees with each other. Fig. 3 shows this integrated screen.

FIG. 3.



It will be noted (see Fig. 3) that some of the holes partially overlap each other. The numbers in the holes show the number of *hundredths of a millimetre* that that particular part of the lens was in error. The heavy circles represent the positions in which the lens focused too short, and the light circles where it focused too long. The arrangement of the holes is also exhibited in Table I.

We used every precaution possible to eliminate local errors. The screens had been in the dome room for several hours pre-

vious to making the photographs in order that they might be of the same temperature as the lens. The screens were constructed carefully and oriented so that the centre of the screen was superimposed on the centre of the objective. Each set of five exposures was made on the same plate. The first exposure was in the centre of the plate and the remaining four grouped symmetrically around the centre one, displaced just enough so that their patterns did not overlap each other. The plates were then measured on a measuring engine, one set each by Prof. S. G. Barton and the writers. The results are exhibited in Table I. It will be noted that Dr. Barton measured only those plates which were made before the screens were turned, through 45 and 90 degrees respectively. The agreement between his measures and those of the writers' are satisfactorily accordant.

If one, by means of formula (1), compute A , the distance from a fixed plane, of the juncture of the rays coming from two holes, he will find, except in the case of a perfect objective, that

$$A = f(\phi, r, \lambda).$$

If when r and λ are constant, A shows a dependence on ϕ , the lens is astigmatic. If the astigmatism is regular and small we may assume, as Hartmann does, that there is one meridional section, making an angle of ϕ_0 with some arbitrarily chosen zero meridional section for which A is a minimum, and another making an angle of $\phi_0 + 90^\circ$ for which A is a maximum; and further that, following Hartmann's notation, if ${}_\phi A$ denote the value of A in a meridional section making an angle ϕ with the zero section, then ${}_\phi A$ may be computed by the formula,

$${}_\phi A = \phi_0 A + a \sin^2 (\phi - \phi_0) \tag{2}$$

where a is the numerical difference between the greatest and least value of A for any given zone. Hence,

$$\frac{1}{2} ({}_\phi A + {}_{\phi+90^\circ} A) = \phi_0 A + \frac{a}{2}$$

If one computes ${}_\phi A$ for all meridional sections of any zone of radius r , for which he has observational data (in our case this number varies from 2 to 4), and if he let A^r be the mean of all the values of ${}_\phi A$ thus obtained for any one zone, it is evident that

$$A^r = \phi_0 A + \frac{a}{2}$$

Put now,

$$R = {}_\phi A - A^r$$

then,

$$R = -\frac{a}{2} \cos 2(\phi - \phi_0) \quad (3)$$

Thus, every two meridional sections give two equations for the determination of a and ϕ_0 . Where there are more than two meridional sections, as is true for most of the zones that we measured, normal equations may be formed and solved. This is the method described by Hartmann and applied by him to the 80 cm. refractor of the Potsdam Observatory. In making the test of the Potsdam refractor, Hartmann constructed the screen so that two zones had openings on more than two diameters and solving the normal equations, formed from the measures of these zones, he found that they gave fairly accordant results for those two zones; that is, the value of a , and ϕ_0 obtained from the solutions for the two zones did not differ widely. We had openings on more than two diameters in 17 zones. We formed the normal equations for each of these zones, and solved them for the quantities a and ϕ_0 . The value of ϕ_0 for all these zones showed little if any tendency to collect around any meridional section. The results of the computation are found in column 15 of Table I.

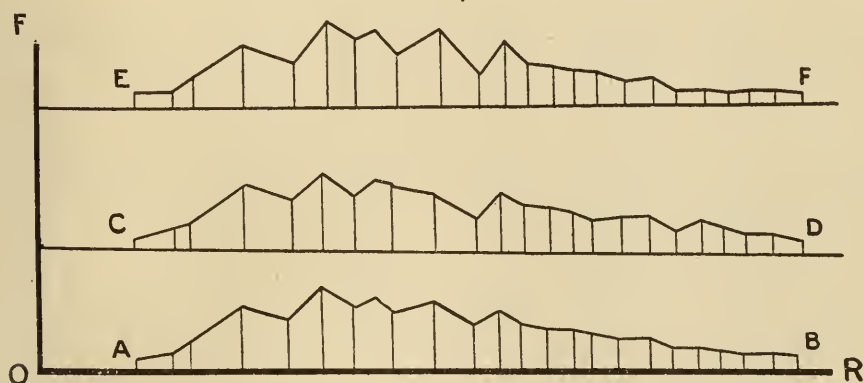
Having obtained a and ϕ_0 for any one zone, we computed R' by substituting in equation (3) the value of ϕ_0 and a found by computation. These quantities R are the computed astigmatisms. The results thus obtained show clearly that there is no regular astigmatism in the lens.

Table I is a summary of the arrangement of the openings in the screen, and the results of the measures. For the sake of ready reference, we give here a description of the table. All linear magnitudes are given in millimetres. Column 1 contains the radii of the zones, column 2 the angles that the meridional section made with a meridional section parallel to the equator, measured in a counter clock-wise direction as seen from the eye end of the telescope. Columns 3, 4, and 5 contain the quantities ϕA^r , A^r , and R as determined by Marriott, where ϕA^r is the distance of the focus from the plane P_2 (Fig. 1), *i.e.* from the plane of the photographic plate which was exposed farthest from the objective, as determined by the juncture of the rays from two openings,¹ in a zone of radius r , and in a plane making an angle ϕ with a plane parallel to the equator, A^r the means of the ϕA^r in any zone and R are the astigmatisms. Columns 6, 7, and 8 contain

the same quantities as determined by Miller, columns 9, 10 and 11 the values as determined by Barton, column 12 contains A^r_m the means of A^r , as determined by Marriott and Miller, column 13 the mean of the R 's as determined by the same observers, columns 14 and 15 the value of a and ϕ_0 as computed by equation (3), column 16 the computed astigmatisms, column 17 the value $\Delta = R - R'$. Even a casual glance at Table I will show that in the region of the zone $r = 5$ inches, the lens focuses shorter than at any other place.

The curves in Fig. 4 are the curves of zonal error; the abscissa of any point is the radius of zone, and the corresponding

FIG. 4.



ordinate is the quantity A_r diminished by a constant and multiplied by 25. So that the difference of any two ordinates is 25 times the difference in the focal length of two zones; that is, the errors are magnified 25 times. The actual difference between the greatest and least focal length of any two zones is less than 1.1 mm. The curves EF , CD , and AB are respectively the graphs of the measures made by Miller and Marriott, and the mean of those measures.

We computed the diameters, d_i , of the circles of confusion for each of the 24 zones in that plane, whose distance from the plane P_2 is A_o where A_o is determined by Hartmann's formula:

$$A_o = \frac{r_k A_k + r_h A_h}{r_h + r_k}.$$

where h and k are determined by the condition that no diameter of confusion shall be greater than d where

$$d = 2r \frac{(A_s - A_o)}{F},$$

TABLE

r	Φ	ϕA_r	A_r	R_1	ϕA_r	A_r	R_2
288.92	22.5°	101.62	101.13	-.49	101.70	101.18	-.52
	67.5	101.00		+.12	101.00		+.18
	112.5	101.03		+.10	101.07		+.11
	157.5	100.85		+.27	100.94		+.24
279.40	0.0	100.99	101.25	+.26	100.90	101.20	+.29
	45.0	101.14		+.10	101.15		+.04
	90.0	101.52		-.27	101.43		-.24
	135.0	101.34		-.09	101.29		-.09
269.87	0.0	101.59	101.23	-.36	101.63	101.18	-.45
	45.0	101.10		+.13	100.80		+.38
	90.0	101.07		+.15	101.20		-.02
	135.0	101.14		+.09	101.09		+.09
260.35	22.5	101.72	101.34	-.38	101.70	101.16	-.54
	67.5	101.44		-.10	101.15		+.01
	112.5	101.32		+.02	101.01		+.15
	157.5	100.87		+.46	100.78		+.38
250.82	22.5	101.67	101.49	-.12	101.22	101.27	+.06
	67.5	101.48		+.01	101.33		-.06
	112.5	101.63		-.14	101.48		-.21
	157.5	101.25		+.24	101.07		+.21
241.30	0.0	101.88	101.27	-.61	101.85	101.22	-.63
	45.0	100.93		+.34	100.87		+.31
	90.0	101.20		+.07	101.44		-.22
	135.0	101.05		+.21	100.71		+.51
233.04	0.0	101.90	101.56	-.34	101.60	101.43	-.18
	45.0	101.32		+.23	101.34		+.09
	90.0	101.76		-.20	101.54		-.12
	135.0	101.24		+.32	101.22		+.21
222.25	22.5	101.50	101.51	+.01	101.42	101.37	-.05
	67.5	101.48		+.03	101.36		+.01
	112.5	101.30		+.21	101.15		+.22
	157.5	101.75		-.24	101.56		-.19
212.75	22.5	101.65	101.48	-.17	101.57	101.48	-.09
	67.5	101.53		-.06	101.51		-.03
	112.5	101.31		+.16	101.43		+.06
	157.5	101.41		+.07	101.43		+.06
203.20	0.0	101.56	101.54	-.02	101.43	101.52	+.09
	45.0	101.14		+.39	101.19		+.32
	90.0	101.55		-.01	101.58		-.07
	135.0	101.90		-.36	101.86		-.35
193.67	45.0	101.52	101.64	+.11	101.49	101.57	+.08
	135.0	101.75		-.11	101.65		-.08
184.15	0.0	101.68	101.67	-.01	101.66	101.67	+.01
	45.0	101.41		+.26	101.37		+.29
	90.0	102.08		-.40	101.92		-.26
	135.0	101.52		+.15	101.71		-.05
174.62	0.0	102.07	101.86	-.21	102.34	101.99	-.35
	90.0	101.65		+.21	101.65		+.35

I.

ϕA^r	A^r	R_3	A_n^r	R	a	Φ_0	R'	Δ
101.01	100.88	-.13	101.15	-.51 +.15 +.10 +.26	.62	27°36'	-.30 -.05 +.30 +.05	-.21 +.20 -.20 +.21
100.74		+.13						
100.92	101.30	+.38	101.22	+.27 +.07 -.25 -.09	.54	98°45'	+.26 +.08 -.26 -.08	+.01 -.01 +.01 -.01
101.69		-.38						
101.03	100.90	-.13	101.20	-.41 +.25 +.07 +.09	.50	170°45'	-.24 +.08 +.24 -.08	-.17 +.17 -.17 +.17
100.76		+.13						
101.14	101.00	-.14	101.25	-.46 -.05 +.09 +.42	.72	42°45'	-.27 -.23 +.27 +.23	-.19 +.18 -.18 +.19
100.85		+.14						
101.24	101.33	+.09	101.38	-.03 -.02 -.17 +.22	.28	82°37'	+.07 -.12 -.07 +.12	-.10 +.10 -.10 +.10
101.42		-.09						
100.78	100.85	+.07	101.24	-.62 +.34 -.08 +.36	.55	1°03'	-.26 -.01 +.26 +.01	-.36 +.35 -.34 +.35
101.91		-.07						
101.11	101.38	+.27	101.49	-.26 +.16 -.16 +.26	.14	22°30'	-.05 -.05 +.05 +.05	-.21 +.21 -.21 +.21
101.64		-.27						
101.05	100.90	-.15	101.44	-.02 +.02 +.21 -.21	.32	180°00'	-.11 +.11 +.11 -.11	+.09 -.09 +.10 -.10
100.76		+.15						
101.48	101.42	-.06	101.48	-.13 -.04 +.11 +.06	.26	33°48'	-.12 -.05 +.12 +.05	-.01 +.01 -.01 +.01
101.37		+.06						
101.43	101.49	+.06	101.53	+.03 +.36 -.04 -.35	.71	134°36'	+.00 +.35 -.00 -.35	+.03 +.01 -.04 -.00
101.56		-.06						
102.02	101.77	-.25	101.60	+.09 -.09	.18	135°00'	+.09 -.09	-.00 -.00
101.53		+.25						
101.54	101.50	-.04	101.67	-.00 +.27 -.33 +.06	.39	106°14'	+.17 +.11 -.17 -.11	-.17 +.16 -.16 +.17
101.47		+.04						
102.20	101.90	-.30	101.93	-.27 +.27	.54	0°00'	-.27 +.27	-.00 +.00
101.61		+.30						

TABLE

r	Φ	ϕA^r	A^r	R_1	ϕA	A^r	R_2
165.10	0.0°	101.15	101.47	+ .32	101.25	101.46	+ .21
	45.0	101.62		- .15	101.57		- .12
	90.0	102.05		- .57	101.97		- .52
	135.0	101.07		+ .40	101.03		+ .43
149.22	0.0	101.97	101.86	- .11	102.60	102.14	- .46
	90.0	101.75		+ .11	101.68		+ .46
133.35	22.5	101.54	101.99	+ .45	101.28	101.75	+ .47
	67.5	101.38		+ .61	101.06		+ .69
	112.5	102.50		- .50	102.30		- .55
	157.5	102.55		- .55	102.35		- .60
127.00	0.0	102.45	102.05	- .40	102.47	102.09	- .38
	45.0	102.05		+ .00	101.94		+ .16
	90.0	101.20		+ .85	101.13		+ .96
	135.0	102.51		- .46	102.84		- .75
116.84	45.0	101.87	101.77	- .10	102.07	102.02	- .06
	135.0	101.66		+ .10	101.96		+ .06
107.95	22.5	102.71	102.12	- .59	102.86	102.30	- .56
	67.5	102.80		- .68	102.97		- .67
	112.5	101.47		+ .65	101.76		+ .54
	157.5	101.50		+ .62	101.62		+ .68
95.25	45.0	101.91	101.72	- .19	101.69	101.66	- .04
	135.0	101.52		+ .19	101.62		+ .04
76.20	0.0	102.34	101.98	- .36	102.17	101.93	- .24
	90.0	101.62		+ .36	101.69		+ .24
57.15	22.5	100.84	101.30	+ .46	100.84	101.45	+ .61
	67.5	100.98		+ .32	101.27		+ .18
	112.5	102.07		- .77	101.99		- .54
	157.5	101.31		- .01	101.71		- .26
50.80	0.0	100.94	101.27	+ .33	101.92	101.19	+ .27
	45.0	101.86		- .58	101.78		- .59
	90.0	100.61		+ .66	100.35		+ .84
	135.0	101.68		- .41	101.69		- .50
38.10	0.0	100.68	101.04	+ .35	100.84	101.18	+ .34
	90.0	101.38		- .35	101.52		- .34

(All linear magnitudes in this

I.—Continued

ϕA^r	A^r	R_3	A_n^r	R	a	Φ_0	R'	Δ
100.75	100.95	+.20	101.46	+.26 -.13	.96	72°59'	+.39 -.26	-.13 +.13
100.16		-.20		-.54 +.41			-.39 +.26	-.15 +.15
102.08	101.86	-.22	102.00	-.28	.56	0°00'	-.28	-.00
101.64		+.22		+.28			+.28	+.00
101.40	101.55	+.15	101.87	+.46 +.65	1.57	138°05'	+.48 +.60	-.02 +.05
101.71		-.15		-.53 -.58			-.48 -.60	-.05 +.02
102.43	101.63	-.80	102.07	-.38	1.45	165°50'	-.64	+.26
100.83		+.80		+.08 +.90 -.60			+.34 +.64 -.34	-.26 +.26 -.26
102.67	102.55	-.12	101.89	-.08	.16	45°00'	-.08	-.00
102.44		+.12		+.08			+.08	+.00
101.62	101.40	-.12	102.21	-.57 -.67	1.75	46°50'	-.54 -.61	-.03 -.06
101.19		+.12		+.59 -.65			+.54 +.61	+.05 +.04
102.43	102.08	-.35	101.68	-.11	.22	45°00'	-.11	-.00
101.72		+.35		+.11			+.11	+.00
102.43	101.85	-.58	101.95	-.30	.60	0°00'	-.30	-.00
101.27		+.58		+.30			+.30	+.00
101.50	101.03	-.47	101.37	+.53 +.25	1.24	127°25'	+.59 +.19	-.06 +.06
100.56		+.47		-.65 -.13			-.59 -.19	-.06 +.06
99.94	99.90	-.04	101.23	+.30	.46	8°00'	-.22	+.52
99.87		+.04		-.59 +.75 -.46			-.06 +.22 +.06	-.53 +.53 -.52
101.49	100.77	-.72	101.11	+.34	.68	0°00'	+.34	+.00
100.06		+.72		-.34			-.34	-.00

table are given in millimetres.)

where s takes the values h and k , and F is determined by the Gauss-Hartmann method and is found to be 11,010.9 mm. (433.5 inches).

TABLE II.

I	2	3	4	I	2	3	4
r	d	d	d	r	d	d	d
288.92	.133	.158	.143	174.62	.129	.139	.138
279.40	.073	.146	.106	165.10	.016	.015	.002
269.87	.080	.147	.111	149.22	.110	.055	.135
260.35	.030	.150	.085	133.35	.127	.052	.092
250.82	.033	.097	.028	127.00	.132	.122	.130
241.30	.055	.116	.083	116.84	.069	.097	.084
233.04	.057	.032	.015	107.95	.130	.141	.135
222.25	.036	.050	.003	95.25	.048	.022	.037
212.75	.024	.008	.010	76.20	.071	.052	.064
203.20	.043	.001	.026	57.15	.010	.053	.066
193.67	.071	.019	.047	50.80	.011	.026	.010
184.15	.076	.046	.066	38.10	.075	.020	.021

Table II gives the diameters of the circles of confusion for each of the 24 zones in the plane at a distance A_0 from P_2 . These diameters are expressed in *hundred-thousandths of the focal length*. The maxima of these diameters of confusion as determined by Marriott and Miller are respectively .133 and .158, while the maximum of the diameters as determined by using the mean of the measures of Marriott and Miller is .143. This we have called the "Resultant" of the two sets of measures. These quantities might be taken as the characteristic quantity that determines the quality of the objective since Hartmann's quantity " T " is the weighted mean.

It is our custom, in actual practice, to determine the photographic focus by making a series of exposures, changing the focus by one one-hundredth of an inch between successive exposures. We determined the focus one evening recently by the Hartmann method, using a screen that contained eight holes, and also in the usual way, by making a series of exposures. The focuses determined in these two ways were exactly coincident.

Being curious to know the separating power of the objective, we tried it on some close doubles on a few nights when seeing seemed steady. The components of the closest double that we separated were 0.26" apart. But we do not regard this as the final word on the separating power of this objective.

From every standpoint the lens is an excellent one. The Hartmann test shows that the focal discrepancies, the diameters of confusion, and T , the weighted diameter of confusion, are all extremely small.

Hartmann's characteristic quantity " T " was computed by his formula

$$T = \frac{100,000}{F} \frac{\Sigma rd}{\Sigma r} = \frac{200,000 \sum_{n=1}^{24} r^2 (A_n - A_o)}{F^2 \Sigma r},$$

where F is the focal length of the objective.

We found:

- $T = .068$ from Marriott's measures.
- $T = .086$ from Miller's measures.
- $T = .070$ from the "resultant" of the measures of Miller and Marriott.

We also, following Fox's ⁴ suggestion, determined T by making Σrd a minimum. The quantity Σrd was computed by varying by a few hundredths of a millimetre, the quantity A_o , from that determined by the Hartmann formula and computing the corresponding values of Σrd .

TABLE III.

1	2	3	4	5	6	7	8
Marriott	A_o	101.55	101.50	101.45	101.41	101.35	101.30
	Σrd	554.71	539.53	521.32	530.50	565.94	606.80
	T	.073	.069	.067	.068	.072	.078
Miller	A_o	101.51	101.49	101.45	101.40	101.35	101.30
	Σrd	673.14	667.42	603.39	600.17	607.25	623.24
	T	.086	.085	.077	.077	.078	.080
Resultant	A_o	101.50	101.45	101.40	101.35	101.30	101.25
	Σrd	574.48	549.10	547.28	550.07	573.37	603.21
	T	.073	.070	.070	.070	.073	.077

The results are exhibited in Table III. The columns 3, 4, 5, 6, 7, and 8 contain the assumed values of A_o , the value of T , and of Σrd , computed with assumed values of A_o . The value of T , set in bold figures, is obtained by the Hartmann formula.

⁴ *Astrophysical Journal*, vol. 27.

Resins in Paleozoic Plants and in Coals of High Rank. D. WHITE. (*U. S. Geol. Survey, Paper 85 E*, 65.)—The supposed absence of resins from the coals of higher rank has led to the view that the coal-forming floras of the Carboniferous period, to which most bituminous and higher-rank coals belong, were destitute of resin-bearing plants, and that these coals have not at any time existed as peats. From a study of petrified fragments of Carboniferous plants, and from observations of Paleozoic coals ("stone-coals"), the author concludes that some of the Carboniferous coal-forming vegetation contained secretions of a resinous nature which became concentrated in the coals, owing to dehydration and the more rapid decay of the other plant tissues. Lump or exudate resins, as well as canal secretions, were found in Paleozoic coals of low bituminous rank. The failure to detect their presence in coals of higher rank is considered to be due to the changes which the resins undergo during the transformation of the coal. These changes, as shown in the coals of the Cretaceous and Tertiary periods (usually lignites or brown coals), are a darkening of the color to a smoky brown, followed by blackening, cracking, and shrinking of the lumps, which are later reduced to dark brownish-black, spongy or granular residues and finally to a fine, thin, powdery black scale. The reduction of the resins coincides with rapid deoxygenation of the coal, and occurs when the proportion of fixed carbon in the coal substance is 60 to 65 per cent. The qualities essential to the production of high-grade coke are developed at the same time.

The Paraffin Motor. ANON. (*Times Eng. Suppl.*, x, 48.)—Paraffin motors are suitable for powers of from 20 to 100 horse-power and have been constructed up to 180 horse-power. The power obtained is about 10 per cent. less than with petrol, and the consumption is 0.7 to 0.8 pint of paraffin (specific gravity 0.82) per British horse-power hour. The normal speed varies from 500 to 800 revolutions per minute with the size of the motor, and the motor can be run down to one-fourth the normal speed. Paraffin carburettors, for running a petrol engine with paraffin, are not entirely satisfactory. In the paraffin motor the vaporizer is usually heated by the exhaust gases, and the engine is started on petrol, or the vaporizer is heated up by a blast lamp. A lower compression is used than in petrol motors.

Prevention of Corrosion of Iron and Steel. (*Brit. Pat. 11,966 of 1913.*)—The objects are heated up to about 750° C. and subjected to the action of a rapid stream of dry ammonia gas for about an hour and a half, after which the furnace is allowed to cool slowly and the current of gas slackened off. By this means a protective layer of iron nitride, Fe_2N , is formed. The nitrified iron is stated to be proof against atmospheric oxidation. The patentee is H. Hanemann.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

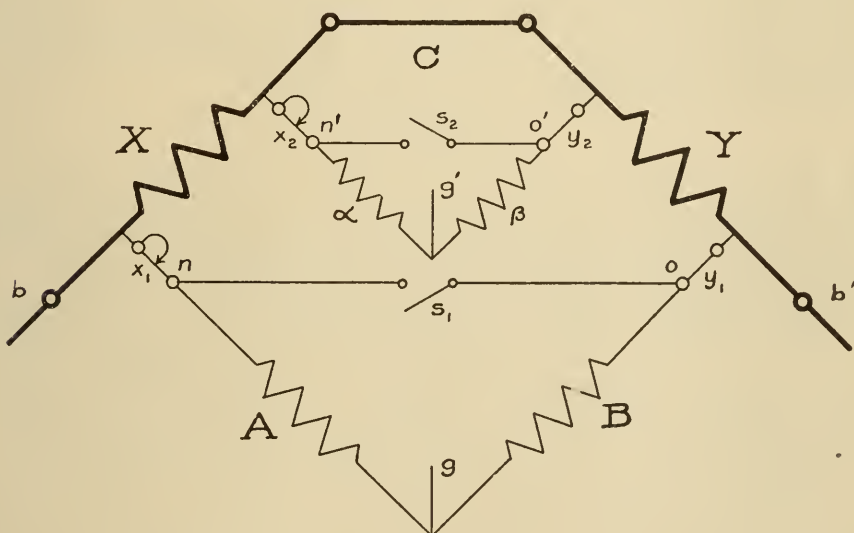
ADJUSTMENTS OF THE THOMSON BRIDGE IN THE MEASUREMENT OF VERY LOW RESISTANCES.†

By F. Wenner and E. Weibel.

[ABSTRACT.]

THE purpose of the paper is to describe two new procedures for carrying out those adjustments which make the correction terms of the Thomson bridge equation negligibly small.

Both procedures require the use of variable double ratio-set so adjusted that for any reading of the dial switches the lack of equality of the two ratios, A/B and α/β (see figure) is so small



that no appreciable error is introduced on this account, and variable low resistances to be used in the connections, x_1 and x_2 , between the terminals of the ratio-set and the potential terminals of the four-terminal conductors under comparison.

One of the procedures is as follows:

(1) With the test current supplied through the terminals b and b' , the bridge is balanced by an adjustment of the dial-switches of the double ratio-set.

* Communicated by the Bureau.

† Scientific Papers of the Bureau of Standards.

(2) With the test current supplied through the terminals n and o , the bridge is balanced by an adjustment of the variable low resistance forming a part of x_1 .

(3) With the test current supplied through the terminals n' and o' , the bridge is balanced by an adjustment of the variable low resistance forming a part of x_2 .

(4) With the test current supplied through the terminals b and b' , the bridge is balanced by an adjustment of the dial-switches of the double ratio-set.

In the other procedure the test current is supplied through the terminals b and b' only, but means are provided for connecting the terminals n and o , and n' and o' by conductors of low resistance. The adjustments are made in four steps, of which (1) and (4) are the same as given above. In (2) the terminals n and o are connected while the bridge is balanced by an adjustment of x_1 and in (3) the terminals n' and o' are connected while the bridge is balanced by an adjustment of x_2 .

Either procedure gives very accurately

$$X = AY/B$$

where X and Y are the resistances of the four-terminal conductors under comparison; and A and B are the resistances between n and g , and g and o , when the final adjustment is made.

Both procedures differ from those previously used mainly in that they do not require changing over to a simple bridge by opening the low resistance connection between the resistances under comparison. Where the resistances under comparison and the resistance of the connection between them are very low, it is more or less impracticable to change over to a simple bridge during the adjustments. In such cases these procedures have been found more satisfactory.

QUANTITATIVE EXPERIMENTS IN RADIOTELEGRAPHIC TRANSMISSION.*

By L. W. Austin.

THE quantitative study of long-distance radiotelegraphic transmission which was begun by the Navy Department in 1909-10 and described in the Bulletin of the Bureau of Standards, 7,

* Scientific paper to be issued shortly by the Bureau of Standards.

p. 315, 1911, Reprint 159, was again taken up in 1912 in connection with the testing of the high-power radio station at Arlington, Va. This station is equipped with a 100-kilowatt Fessenden rotary gap sending set which gives an antenna current of approximately 100 ampères at a wave-length of 3800 metres. The aerial is triangular in shape and suspended between three steel towers, two of which are 450 feet in height, while the third has a height of 600 feet. The capacity of the antenna is 0.01 microfarad and the height to the centre of capacity 400 feet. Short-range experiments showed that the effective height of the Arlington station was only about one-half the height to the centre of capacity of the antenna. This appears to be generally true of land stations, and is probably due to the fact that they are not erected on sufficiently good conducting surfaces as assumed in the theory. The main scientific object of the experiments was the determination of the correctness of the Sommerfeld transmission formula

$$(1) \quad I_R = 120\pi \frac{h_1 h_2 I_s}{\lambda d R} \cdot e^{-\frac{0.0019 d}{\sqrt{\lambda}}}$$

where h_1 is the effective height of the sending antenna, h_2 the corresponding height of the receiving antenna, I_s the sending antenna current, λ the wave-length, d the distance between the two stations, and R the effective high-frequency resistance of the receiving antenna system,

The strength of the received signals was measured on the *U. S. S. Birmingham*, which made a voyage to Gibraltar and return for the carrying out of the tests. The total height of the Birmingham's antenna was 130 feet, and the height to the centre of capacity 114 feet. The effective high-frequency resistance was 50 ohms at 3800 metres. Signals were received by means of an electrolytic detector, and their intensity measured by the shunted telephone method which was described in the paper already cited. From the data thus obtained it was possible to determine the received antenna current I_R .

The table shows the results. Column 5 gives the experimental values as obtained from the smoothed curve of observations, and column 3 the values as calculated from the Sommerfeld formula (1). Column 4 gives the calculated values as obtained from a

semi-empirical formula (2) made up of the first term of the theoretical formula, but with the absorption term replaced by the absorption term which was found to be correct in the experiments made in 1910. The values in column 4 are seen to be in very fair agreement with the observed values.

$$(2) \quad I_R = 120\pi \frac{h_1 h_2 I_s}{\lambda dR} \cdot e^{-\frac{0.0015 d}{\sqrt{\lambda}}}$$

The Sommerfeld theory takes no account of energy which may be brought to the receiving station by means of reflection or refraction in the upper atmosphere, and it is thought probable that it is this portion of the energy which produces the difference between the observed and theoretical results.

ARLINGTON RECEIVED ON THE "SALEM," FEBRUARY-MARCH, 1913.

Distance		Received current 10^{-6} amp.		
Miles	Km.	Calculated		Obs.
		Eq. 2	Eq. 1	
300	556	335	431	410
400	740	200	278	300
500	925	128	195	225
600	1110	85.2	140	160
800	1480	40.7	79.0	95
1000	1850	20.7	47.6	59
1200	2220	11.0	29.7	34
1500	2780	4.42	15.3	19
2000	3700	1.07	5.65	5.0
2500	4630	0.28	2.20	.....
3000	5560	0.74	0.89	.....

In connection with these experiments a comparison was also made between the received signals from the Fessenden spark set and those from a Poulsen arc temporarily installed at the Arlington station. It was found that, for distances up to about 1000 miles, the received antenna currents were practically the same, for the same sending antenna currents. At greater distances the arc seemed to be superior, as measured on the *Salem* and also at the U. S. naval radio station at Colon, Canal Zone.

VARIOUS MODIFICATIONS OF THERMOPILES HAVING A CONTINUOUS ABSORBING SURFACE.*

By W. W. Coblentz.

IN a previous paper (Bulletin Bureau of Standards, No. 188) an account was given of the construction and the behavior of thermopiles composed of bismuth and silver wires with rectangular absorbing surfaces of tin attached to the junctures of these two metals. The novelty of the design consists in a series of overlapping receivers, forming a continuous surface which has all the disadvantages of a good bolometer, with none of the disadvantages of that well-known instrument.

The present paper deals with the construction and the behavior of various modifications of this type of thermo-element, adapted to various problems in biology, physiology, psychology, physics, and astronomy. In the present paper 22 different topics are discussed, and from among the numerous experimental tests a few may be cited.

It was found that by joining the thermo-elements—two in series-parallel—the heat capacity of the composite receiver was reduced and the time to attain temperature equilibrium, after exposing the receiver to radiation, was shortened so that a maximum galvanometer deflection is attained in three to five seconds.

It is shown that the radiation sensitivity of a composite receiving surface is proportional to the square root of the area of the exposed surface. However, this relation does not hold true for the single receivers attached to the individual thermo-junctions. In the latter there is an optimum size of the receiver required to compensate for the loss of heat by conduction along the wires, and by radiation from the surface. Using thermo-elements of bismuth wire 0.1 mm. in diameter, and silver wire 0.036 mm. in diameter, this optimum size of receiver is of the order of 1.5 by 1.5 mm.

In the tests on the relation of external resistance to the internal resistance of the galvanometer it is shown that there may be a considerable departure from equality of the two resistances (the galvanometer resistance may be two to three times the internal [thermopile] resistance) without seriously affecting the efficiency of the galvanometer.

* Scientific Papers of the Bureau of Standards.

Tests are given of various samples of bismuth wire, showing that the thermo-electric power against silver varies from 75 to 80 microvolts.

The construction and test of sensitivity of a thermopile of bismuth alloy is given. The alloy was bismuth + 5 per cent. tin. Wires of alloy when joined with pure bismuth wire had a thermo-electric power of 127 microvolts. In spite of this high intrinsic thermo-electric power, the radiation sensitivity of the completed thermopile was not any higher than that of the thermopiles constructed of bismuth and silver, which elements have a 55 per cent. lower thermo-electric power. This is owing to the high resistance of the alloy.

A thermopile constructed of bismuth and iron, which like the aforementioned alloy has a higher thermo-electric power, was no more sensitive than the thermopiles constructed of bismuth and silver. The conclusion arrived at is that the production of a thermopile having a high radiation sensitivity is more dependent upon nicety of construction than upon the use of materials having a high thermo-electric power.

The construction and tests of a radiometer attachment for monochromatic illuminators are given. This device consists of a linear thermopile, which moves in vertical ways in front of the exit slit of a spectroscope. It is useful in measuring the energy value (mechanical equivalent) comprised in the different wavelengths of light used as stimuli, in biological, chemical, physical, and physiological investigations.

The method of construction and tests are given of a thermopile to be used for absolute measurements of radiation. The device consists of a linear thermopile of bismuth and silver, with a continuous receiving surface, in front of which is situated a strip of manganin or platinum, which is blackened electrolytically with platinum black. This strip of metal is exposed to radiation and in turn radiates to the thermopile, which causes a galvanometer deflection. The strip of metal is then heated electrically to cause a similar deflection of the galvanometer needle; and the power expended gives a measure of the radiation in absolute value. The instrument gives a value of the coefficient of total radiation of a black body which is in excellent agreement with values obtained by other methods.

Among the group of special designs, the stellar thermo-

elements may be mentioned. When used with a reflecting mirror, 92 cm. (36 inches) in diameter, and an ironclad Thomson galvanometer (also described in this paper) of ordinary sensitivity, it was possible to make quantitative measurements of the total radiation from stars down to the 5.3 magnitude, while high qualitative measurements were made on stars down to the seventh magnitude. The application of the thermo-element to solve astronomical problems, therefore, appears to be feasible.

The design and tests are given of an absolute thermopile for the measurement of nocturnal radiation; also of a thermopile to be used as a photometer to measure the blackness of star images on photographic plates. A novel design for a special biological problem consisted in the construction and testing of a linear thermopile, in which the receiver was bent into a U-shaped trough. The test showed that if the object (say muscle or nerve) evolved heat at the rate of 1×10^{-9} g-cal. sec.⁻¹ it can be detected.

The appendix consists of notes on (1) galvanometer mirrors, (2) vacuum galvanometers, (3) the most efficient combination of thermopile and galvanometer resistance, and (4) the maintenance of high vacua by means of metallic calcium. The calcium is contained in a quartz-glass tube which is attached to the vacuum (stellar) thermopile. The thermopile container is exhausted by means of an oil pump, and the stopcock is closed. Thereafter the vapors given off are removed by heating the metallic calcium with an alcohol lamp. The device is thoroughly reliable, as evidenced by the fact that it was carried to the Lick Observatory, Mt. Hamilton, Calif., and back, the vacuum having been maintained for over two months with no signs of failure of the calcium.

MEASUREMENTS ON STANDARDS OF RADIATION IN ABSOLUTE VALUE.*

By W. W. Coblentz.

ONE of the chief needs in the measurement of radiant energy is a convenient standard against which the radiometer may be calibrated. The great utility of a seasoned carbon incandescent lamp as a photometric standard is well recognized, and such a

* Scientific Papers of the Bureau of Standards.

lamp has every desideratum of a standard of radiation, when calibrated against a black body, as the primary standard of radiation. The object of the present investigation is to establish and maintain a standard of radiation in the form of seasoned incandescent lamps, and to issue to experimenters similar standards of radiation, whereby may be obtained an accurate calibration of their radiometers in absolute value.

The incandescent lamps were standardized by two independent methods which are in agreement within 0.5 per cent. The first method consisted in comparing the radiation from a black body with the radiation from the incandescent lamp, assuming a value for the coefficient (the "Stefan-Boltzmann constant") of total radiation of the black body. For this purpose a thermopile was directed towards the black body, then towards the incandescent lamp. The second method consisted in a direct measurement, in absolute value, of the energy of the incandescent lamp with a modified form of Ångström pyrheliometer. This pyrheliometer gave a value ($\sigma = 5.61 \times 10^{-12}$ watt cm^{-2} deg^{-4}) for the coefficient of total radiation which is close to the value of this constant as determined by various other methods differing widely in character.

The standard of radiation, in terms of these incandescent lamps, may therefore be considered fairly well established—at least, sufficient to fulfil present requirements. In the lamps issued to the public the intensity of the radiant energy per mm^2 at a distance of 2 m. from the lamp is certified, when the lamp is operated on a given current and voltage.

For rough calibrations of radiometers in absolute measure a sperm candle of a Hefner lamp may be used. For the sperm candle, burning at a mean height, the intensity of the total radiation at a distance of 1 m. from the flame may be taken to be 29×10^{-6} g-cal per cm^2 per sec. The intensity of the total radiation at a distance of 1 m. from the Hefner lamp *without a diaphragm* may be taken to be 26×10^{-10} g-cal per cm^2 per sec. The paper gives data also for the radiation from the Hefner lamp with a diaphragm, having a definite opening, and situated at a definite distance in front of the lamp. The flame standards are unsteady, and various reasons are given for discouraging their use in refined radiation measurements.

A DIRECT READING INSTRUMENT FOR MEASURING THE
LOGARITHMIC DECREMENT AND WAVE-LENGTH
OF ELECTROMAGNETIC WAVES.*

By Frederick A. Kolster.

[ABSTRACT.]

THE paper describes a new instrument for facilitating the measurement of the logarithmic decrement and wave-length of high-frequency oscillations such as exist in the wave trains emitted from radio transmitting stations. The complete theory and design of the instrument are given, as well as experimental data. The measurement of the logarithmic decrement at radio stations is of particular importance, since the United States laws governing radio communication specify, among other things, that the logarithmic decrement per complete oscillation in the wave train emitted by the transmitter shall not exceed two-tenths.

When persistent oscillations of single frequency are emitted from a radio transmitting station much more selective receiving apparatus may be employed with advantage at receiving stations, permitting sharp tuning with consequent minimizing of interference caused by stations other than those with which communication is desired. It is desirable, therefore, that the logarithmic decrement, which is a measure of the decay of a train of waves, be as small as possible.

The instrument described operates in accordance with the method of Bjerknes, but the task of making careful observations and necessary calculations required by the Bjerknes formula is eliminated.

An important element of the instrument is a variable condenser, the capacity of which varies in accordance with the law of geometric progression.

The simplified Bjerknes formula may be written as

$$\delta_1 + \delta_2 = \pi \frac{C_r - C}{C} = \pi \frac{\Delta C}{C}$$

where δ_1 is the decrement of the circuit to be measured, and δ_2 the known decrement of the measuring instrument. C_r is the value

* Scientific Papers of the Bureau of Standards.

of capacity of the variable condenser at the point of resonance, and C is a slightly different capacity of such a value that the energy in the instrument at resonance is reduced to one-half.

Since the variable condenser in the instrument varies in accordance with the law of geometric progression, then for any given displacement of the condenser plates the percentage change of capacity $\frac{\Delta C}{C}$ will be constant throughout the range of motion of the condenser. It is therefore possible to attach to this condenser an accurately divided scale from which values of $\delta_1 + \delta_2$ can be read directly.

The methods used for the determination of δ_2 , the decrement of the instrument, are discussed and experimental data indicating the accuracy with which measurements of logarithmic decrements can be made are given. Several instruments have been constructed for the Army and Navy and for the radio inspection service of the Department of Commerce.

EQUILIBRIUM IN THE SYSTEM, LEAD ACETATE, LEAD OXIDE, WATER.*

By R. F. Jackson.

IN order to obtain a firm basis for investigating the clarification of raw sugar, a study has been made of the basic acetates of lead from the standpoint of the Phase Rule. The analysis of the basic lead acetates was performed by measuring the volume of standard acid neutralized by the basic lead and the volume of reagent required for the total precipitation of lead. For precipitating lead either sulphuric acid or sodium oxalate was used in excess. In the former case the excess was measured by precipitation with barium chloride, in the latter by titration with potassium permanganate.

The basic acetates were synthesized by the interaction of neutral lead acetate and lead hydroxide. The reaction proceeded very rapidly and produced some striking phenomena. In one instance the reacting substances quickly formed a solution which

* Scientific Papers of the Bureau of Standards.

rapidly solidified to a relatively insoluble crystalline compound. In another case the unmixed components had the appearance of nearly dry solid material, but upon vigorous shaking formed a mobile liquid. The explanation of this is in the formation of a very soluble basic compound. The equilibria were established by at least 48 hours' agitation at constant temperature. The solid phases capable of existence are as follows:

Neutral lead acetate $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{H}_2\text{O}$ consists of brilliant monoclinic prisms. It is stable in equilibrium with solutions of itself, and its solubility increases very rapidly in solutions of increasing basicity. Its saturation curve is continuous with that extending into acid solutions. The solubility of the neutral acetate in neutral solutions is 35.50 per cent. The extreme basic solution in equilibrium with the neutral acetate contains 15.89 per cent PbO and 48.95 per cent. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$.

The tetra-lead monoxy hexa-acetate $3\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{PbO} \cdot 3\text{H}_2\text{O}$ crystallizes in needles which are usually minute, but may attain the length of half a centimetre. It is exceedingly soluble in water and forms highly refracting solutions of density 1.93 to 2.28. The solutions contain at the extremes of the saturation curve 15.89 per cent. PbO , 48.95 per cent. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$, and 24.74 per cent. PbO , 49.21 per cent. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$. The substance is unstable in contact with solutions of itself, but for its existence in equilibrium with a solution it depends upon an excess of dissolved basic lead. On account of the small size and softness of the crystals and the high density of the mother liquor it is practically impossible to isolate the pure substance.

The tri-lead dioxy diacetate $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{PbO} \cdot 4\text{H}_2\text{O}$ consists of ill-formed needles which may be so small as to seem amorphous. It is capable of existence in contact with solutions of itself, but under such conditions has a solubility of but 13.3 per cent. Its saturation curve, however, possesses a very great length. The extremes of solubility are 7.4 per cent. PbO , 4.8 per cent. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$, and 24.74 per cent. PbO , 49.21 per cent. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$.

Lead hydroxide is stable in equilibrium with solutions containing as much as 7.4 per cent. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$.

A study of the equilibria of the chemical reactions yields an interpretation of the course of the saturation curves.

NATIONAL STANDARD HOSE COUPLINGS AND FITTINGS FOR PUBLIC FIRE SERVICE.*

By P. L. Wormeley.

1. The movement for the adoption of standard fire hose couplings dates from the great Boston fire of 1872, which showed the impossibility of the fire departments of adjacent towns acting in unison when provided with the diverse sizes of hose fittings then prevailing.

2. The matter was taken up at the first Convention of Fire Engineers, in 1873, and was discussed at various conventions in succeeding years. The resolutions gradually became more definite, although little was accomplished toward bringing about the desired changes until the agitation received a new impetus from the Baltimore fire in 1904, when neither the Washington, Philadelphia, nor New York fire engines, on their arrival, could make connection with the local fire hydrants.

3. This condition led the Merchants and Miners Transportation Company, in April, 1904, to request the Secretary of the Department of Commerce and Labor to investigate the subject of fire hose couplings. The Secretary referred the matter to the Bureau of Standards, and, in the investigation which followed, it was found that there was a great diversity in sizes and threads of couplings throughout the United States. It was evident that considerable expense would be involved in changing from one standard to another, and therefore, at the conference of the committees of the National Fire Protection Association and American Water Works Association, held in New York City, April 24, 1905, the Bureau of Standards proposed the adoption either of the thread which could be shown to be most extensively used, or that thread which possessed the greatest advantages in other respects. Following the latter course, the conference resolved that $7\frac{1}{2}$ threads per inch should be recommended for $2\frac{1}{2}$ -inch fire hose couplings. This thread was not regarded as an ideal standard, but was considered the most practicable basis for unification under prevailing conditions.

4. At the annual convention of the International Association of Fire Engineers, at Duluth, in 1905, this standard was adopted after lengthy discussion, and at Dallas, in 1906, the convention reaffirmed the action taken at Duluth, and made its record complete

* Abstract of Circular No. 50.

by adopting the National Standard Specifications covering couplings of 3 and $3\frac{1}{2}$ inches inside diameter, each to have 6 threads to the inch, and a $4\frac{1}{2}$ -inch coupling having 4 threads to the inch.

5. Since then a dozen large organizations have adopted the national standard. The report of the committee of the American Society of Mechanical Engineers, adopted December 3, 1913, treats its present status in a very clear and comprehensive manner, with suggestions for converting non-standard couplings for serviceable interchange with the national standard. Up to 1913 the national standard had been put into service in 73 cities or towns, either as new equipment or by adaptation of non-standard couplings to interchange with the standard.

STANDARDIZATION OF NO. 200 CEMENT SIEVES.*

By Rudolph J. Wig and J. C. Pearson.

THIS paper reports the results of an investigation undertaken for the purpose of developing greater uniformity in fineness determinations of cement as ordinarily made on certified No. 200 sieves.

It has been observed that sieves differed considerably in their indications of fineness, and an attempt was made to establish the range in sieving values of as many sieves previously certified by the Bureau of Standards as could be located. Carefully prepared samples of cement were therefore sent to all laboratories known to possess certified sieves, and with the coöperation of these laboratories results of tests on about 160 sieves were obtained. These results showed a variation of nearly 5 per cent. in the fineness of the standard sample, which was assumed, from the study of the results, to be 77.00 per cent. passing the standard No. 200 sieves.

A study was made of the possible causes of discrepancies in sieves, and it was found that no reliable estimates of sieving values could be made from the ordinary certification measurements, nor from other proposed methods of standardizing, except by actually performing the sieving tests with a sample of known fineness. The most probable explanation for these unaccounted-for discrepancies seems to be in the irregular spacing of the warp wires, which cause a variation of 100 per cent. or more in the size of the sieve openings. This very large variation

* Abstract of Technologic Paper No. 42 of the Bureau of Standards.

in size of openings is found to exist in, and to be characteristic of, all No. 200 sieves. It was therefore concluded that such sieves can only be properly standardized by sieving tests, made in strict accord with the specifications, these tests to be supplemented by a brief microscopic examination of the sieve cloth to insure its general uniformity and good quality.

The standardization of sieves tests involves the maintenance of standard samples of cement or other material of similar granulometric composition. A number of finely ground materials were tested to determine their suitability for sieving tests. It was found that normally burned and well-aged cement was better adapted for this purpose than ground quartz, brick, or marble, these four materials having the highest rating in the tests of eleven different materials.

On the basis of the foregoing results a revised specification for Standard No. 200 sieves will be adopted, and standard samples of cement for tests of sieves will be issued by the Bureau at a nominal price. The fineness of the standard samples will be determined on fundamental standard sieves now set aside, which will be replaced by other more exact standards as opportunity offers. Certificates of sieves will, in the future, report the sieving values of the sieves on standard samples from which approximate "corrections" to the sieves can be obtained. The paper discusses the application and use of these sieve corrections in detail.

From the data obtained in the sieving tests a tolerance of 1 per cent. from the specifications in routine fineness determinations is recommended, although means are now available for reducing the error of check tests and other important determinations to 0.5 per cent. or less.

THE INSULATING PROPERTIES OF SOLID DIELECTRICS.*

By Harvey L. Curtis.

Two properties of dielectrics are considered: (1) The volume resistivity and (2) the surface resistivity. The volume resistivity of a material is the resistance in ohms between two opposite faces of a centimetre cube. The surface resistivity is defined as the resistance between two opposite edges of a centimetre square of the surface film which is deposited upon the material.

* Scientific Papers of the Bureau of Standards.

In measuring the volume resistivity, mercury electrodes were employed in order to make good contact, and a guard-ring was used to prevent any errors on account of surface leakage. The effect of the temperature of the specimen, of the humidity of the surrounding air, and of the magnitude and length of application of the applied voltage were studied. The only one of these which, for ordinary laboratory conditions, affects the order of magnitude of the results is the length of application of the voltage, and this is of importance only if the volume resistivity is greater than 10^{13} . Values of the volume resistivity are given in Table I.

TABLE I.

Volume Resistivity of Solid Dielectrics.

(Materials arranged in order of decreasing resistivity.)

Material	Resistivity ohms-cm.	Material	Resistivity ohms-cm.
Special paraffin.....over	5000×10^{15}	Paraffined mahogany.....	40×10^{12}
Ceresin.....over	5000×10^{15}	Stabalite.....	30×10^{12}
Fused quartz.....over	5000×10^{15}	Plate glass.....	20×10^{12}
Hard rubber.....	1000×10^{15}	Hallowax No. 1001.....	20×10^{12}
Clear mica.....	200×10^{15}	Dielectrite.....	5×10^{12}
*Sulphur.....	100×10^{15}	Bakelite No. 5199 RGRB .	5×10^{12}
*Amberite.....	50×10^{15}	Bakelite No. 150.....	4×10^{12}
*Rosin.....	50×10^{15}	Gummon.....	3×10^{12}
*Mica (India ruby slightly stained).....	50×10^{15}	Tegit.....	2×10^{12}
G. E. No. 55 R.....	40×10^{15}	Opal glass.....	1×10^{12}
Hallowax No. 5055 B.....	20×10^{15}		
Mica (brown African clear)	20×10^{15}	Paraffined poplar.....	500×10^9
Bakelite L558.....	20×10^{15}	Bakelite No. G5200RGR..	400×10^9
*Electrose No. 8.....	20×10^{15}	Paraffined maple.....	300×10^9
*Parowax (paraffin).....	10×10^{15}	Bakelite No. 1.....	200×10^9
Glyptol.....	10×10^{15}	Bakelite No. 190.....	100×10^9
*Shellac.....	10×10^{15}	Italian marble.....	100×10^9
Kavalier glass.....	8×10^{15}	Bakelite micarta.....	50×10^9
*Insulate No. 2.....	8×10^{15}	Bakelite No. G5074.....	40×10^9
*Sealing wax.....	8×10^{15}	Black condensite.....	40×10^9
*Yellow electrose.....	5×10^{15}	Yellow condensite.....	40×10^9
*Duranoid.....	3×10^{15}	Vulcabeston.....	20×10^9
*Murdock No. 100.....	3×10^{15}	White celluloid.....	20×10^9
*Yellow beeswax.....	2×10^{15}	Hard fibre.....	20×10^9
Khotinsky cement.....	2×10^{15}	Black galalith.....	20×10^9
*G. E. No. 40.....	1×10^{15}	Lavite.....	20×10^9
*G. E. No. 55A.....	1×10^{15}	White galalith.....	10×10^9
*Moulded mica.....	1×10^{15}	Hemit.....	10×10^9
		Red fibre.....	5×10^9
Unglazed porcelain.....	300×10^{12}	Marble, pink Tennessee...	5×10^9
Redmonite (157,4).....	200×10^{12}	Marble, blue Vermont.....	1×10^9
Black electrose.....	100×10^{12}		
Tetrachlornaphthalene....	50×10^{12}	Ivory.....	200×10^6
Mica (India ruby stained).	50×10^{12}	Slate.....	100×10^6
German glass.....	50×10^{12}	Bakelite No. 140.....	20×10^6

*Apparent resistivity taken after the voltage had been applied for fifteen minutes.

Since the surface resistivity depends upon the surface film, any condition which will affect this film will affect the surface resistivity. Upon the surface of all insulators except the waxy materials a film of moisture collects from the surrounding air. The thickness and conductivity of this film depend upon the material of which the insulator is composed and upon the relative humidity of the surrounding air. For some materials the surface resistance at 1 per cent. humidity is 10^{11} times larger than at 95 per cent. humidity, though for the majority of materials the surface resistance does not change by a factor of more than 10^6 under these conditions. Since the change is not uniform, it has been found necessary to construct curves showing the change of surface resistivity with humidity. These curves will be found in the original article.

A WATTHOUR METER METHOD OF TESTING INSTRUMENT TRANSFORMERS.*

By P. G. Agnew.

RATIO and phase-angle measurements of instrument transformers may easily be made by the use of two precisely similar watthour meters, which may be of either the portable type or of the house type, provided the disk has been graduated in 100 divisions. The meters should be adjusted to very nearly the same rate.

The method depends upon the use of a standard transformer whose ratio and phase angle have been determined in some laboratory equipped for the purpose. The standard transformer must have the same nominal range as the one under test.

For voltage transformers an auxiliary current is passed in series through the current coils of the two meters. The voltage coil of each meter is connected to one of the transformers, and readings taken showing the difference in speeds of the meters. The meters are then interchanged and readings again taken. If the meters have been operating at, or very near, unity power factor, the ratio of the transformer under test is easily computed in terms of the ratio of the standard. The formula is

* Scientific Papers of the Bureau of Standards.

$$\frac{R_2 - R_1}{R_1} = \frac{1}{2} \left(\frac{a_1 - a_2}{a_2} + \frac{b_1 - b_2}{b_2} \right)$$

where R_1, R_2 = ratios of the transformers.

a_1, a_2 = numbers of turns of meter A when connected to transformers 1 and 2, respectively.

b_1, b_2 = same for meter B.

Similarly the difference in phase angles may be determined by running the meters at low power factor, which may be conveniently done by taking the auxiliary current from one of the other phases of a three-phase source. If the meters are working at the power factor $\cos \theta$, current lagging,

$$\tan a_2 = \tan a_1 + \frac{1}{\tan \theta} \left[\frac{a_1 - a_2}{2a_1} + \frac{b_1 - b_2}{2b_1} - \frac{R_2 - R_1}{R_1} \right]$$

where the a 's are the phase angles of the transformers, counted as positive for the reversed secondary voltage leading the primary voltage.

For current transformers the method of connecting the coils is inverted, compared with the case of the voltage transformer. An auxiliary voltage is applied to the voltage coils of the meters in parallel, the current coils being connected alternately to the two transformers. Care should be taken not to open the secondary circuit of a current transformer while current is passing in the primary. The formula for the difference in ratios is the same as for the voltage transformer. The formula for phase angle is correct as given both for the voltage transformer with lagging current and for the current transformer with leading current. If the conditions are *vice versa*, the + sign before the bracketed term should be changed to -.

It is, however, not necessary to depend upon this equation for determining which transformer has the greater phase angle. The following facts may be used as criteria for experimentally determining the question:

1. Adding a non-inductive load to a voltage transformer always tends to lag the secondary voltage.
2. Increasing the resistance in the secondary of a current transformer tends to advance the phase of the secondary current.

The experimental results show that by taking runs of approximately 100 turns each the method is capable of determining ratio to 0.02 per cent. or 0.03 per cent., and phase angle to one

or two minutes. In commercial work shorter runs would suffice. Results as good as this were also obtained with the speed of the meter doubled by shunting the magnets. Separate direct experiments showed that the modern induction meter, even with the drag magnets shunted so as to give double speed for normal torque, will repeat in consecutive runs under constant conditions to a precision of about 0.01 per cent. at full load.

There are cases in which it may be convenient to determine a lump correction for both ratio and phase angle instead of determining and correcting for them separately; for example, the case of a watthour meter and a current transformer metering the power supplied to an inductive load. This may even be extended to the case of the combination of a current and a voltage transformer.

Portable watthour meters are more convenient than the house type with graduated disks, as the trouble of counting is eliminated. In testing current transformers a five-ampère range is more economical of time than a ten-ampère range. One-ampère or two-ampère ranges should not be used with current transformers, as the impedance introduced into the secondary is too great.

It is important that the constants of the standard transformer should have been tested under actual working conditions of load, including the meter.

The accuracy of the method is ample for commercial requirements, the results are independent of ordinary line fluctuations, and no special apparatus is required.

Note on a Theory of Thunderstorms. H. NAGAOKA. (*Mathematico-Physical Soc., Tokyo, Proc.*, vii, 228.)—It is considered that the phenomenon of repeated discharges can be accounted for from the point of view that the thunderclouds form a composite dielectric. The dielectric contains clouds, ions, and air, and the charges are embedded in it. The charges accumulate, the electric field increases in strength, and the wandering of the ions and distribution of cloud particles become favorable for causing a discharge through the intervening layer. Such a composite dielectric will exhibit electric absorption and residual discharge. Further, the disruptive discharge causes the fresh production of ions. The sudden change of pressure in the path of the discharge will sometimes be quite favorable to the condensation of water particles on electrified nuclei. The phenomenon of repeated discharges is, on this account, a natural consequence of electric absorption in cloud masses.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday,
September 2, 1914.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 2, 1914.

MR. J. A. P. CRISFIELD, *Chairman pro tem.*

The following report was presented for first reading:

No. 2605.—Blonck Boiler Efficiency Meter.

The following report was presented for final action:

No. 2597.—George A. Wheeler's Escalator. John Scott Legacy Medal and Premium recommendation adopted.

The following report was reconsidered:

No. 2524.—Sperry's Gyro-Compass. John Scott Legacy Medal and Premium recommendation confirmed.

Amendments to the 1913 Regulations were considered and adopted in their final form.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting, Board of Managers, September 9, 1914.*)

RESIDENT.

MR. GEORGE H. BENZON, JR., 252 Mather Road, Jenkintown Pa.

MR. JOSEPH A. JANNEY, JR., Chestnut Hill, Philadelphia, Pa.

MR. GEORGE C. THOMAS, JR., Chestnut Hill, Philadelphia, Pa.

MR. FRANCIS RAWLE WADLEIGH, 20 South Twenty-first Street, Philadelphia, Pa.

MR. CHARLES H. ZIEGLER, 25 Hancock Street, Riverside, N. J.

NON-RESIDENT.

MR. WEBB L. GIBBS, 7717 Coles Avenue, Chicago, Ill.

MR. W. S. RUGG, Westinghouse Electric and Manufacturing Company, 165 Broadway, New York, N. Y.

MR. H. N. SPICER, Room 1926, 30 Church Street, New York, N. Y.

Changes of Address.

MR. M. D. BURKE, Room 706 Second National Bank Building, southeast corner Ninth and Main Streets, Cincinnati, Ohio.

PROF. JAMES BARNES, Care of Brown, Shipley and Company, 123 Pall Mall, London, England.

DR. ELMER L. CORTHELL, North Egremont, Mass.

MR. JAMES DONALD, 17 Victoria Street, London, S. W., England.

MR. BYRON E. ELDRED, 18 East Forty-first Street, New York, N. Y.

MR. WILLIAM C. FARNUM, 3 Central Street, Winchendon, Mass.

MISS EMILY E. HOWSON, Glen Moore, Chester County, Pa.

MR. GEORGE MCCALL, 1106 Spruce Street, Philadelphia, Pa.

MR. GEORGE MACLEAN, Room, 1613, 220 West Forty-second Street, New York, N. Y.

MR. PARKE D. MASSEY, Hotel Tivoli, Ancon, Canal Zone, R. de Panama.

MR. THOMAS E. MURRAY, Irving Place and Fifteenth Street, New York, N. Y.

MR. FREDERICK J. PEARSON, Station M, 644 East Forty-first Street, Chicago, Ill.

MR. AUGUSTUS SMITH, R. F. D. No. 2, Elizabeth, N. J.

MR. HORACE B. SMITH, 2229 Chelsea Avenue, Walbrook, Baltimore, Md.

MR. HARRISON D. STRATTON, 3837 Market Street, Philadelphia, Pa.

MR. EDWIN D. TUCKER, Little Silver, N. J.

MR. ARTHUR WILLIAMS, Fifteenth Street and Irving Place, New York, N. Y.

MR. EDWARD WOOLMAN, northeast corner Buck and Panmure Roads, Haverford, Pa.

NECROLOGY.

Mr. Richard Young was born in Philadelphia on February 4, 1836. In middle life he removed to Morton, Pa., where he resided for over forty years. He was greatly interested in the educational work of this and neighboring communities. He was connected with a number of local public service corporations, and was elected to fill municipal offices on several occasions. Mr. Young held membership in prominent organizations. He was elected a life member of the Institute on January 20, 1869. He died at Morton on June 20, 1914.

THE FRANKLIN MEDAL.

SAMUEL INSULL, Esq., of Chicago, Illinois, writing under date of December 23, 1913, to the Board of Managers, stated that he had been informed it would be a source of gratification to them if the Institute had available, in addition to such medals already in its gift, a medal to be known as The Franklin Medal, and to be awarded from time to time in recognition of the total contributions of individuals to science or to the applications of physical science to industry, rather than in recognition of any single invention or discovery, however important. He agreed to provide for the founding of this medal under the following general conditions:

1. That an amount not exceeding one thousand dollars should be furnished by him for procuring appropriate designs and dies for the medal and diploma.
2. That the medal should possess distinct artistic merit, and have on one

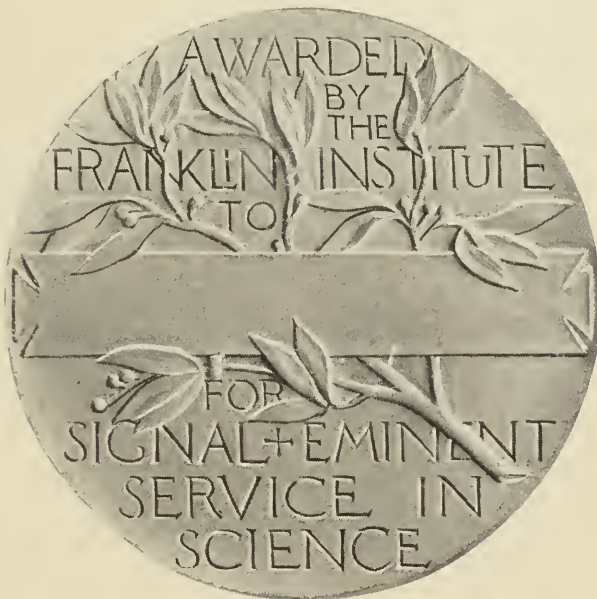
THE FRANKLIN MEDAL

FOUNDED JANUARY 1st, 1914, BY SAMUEL INSULL, ESQ.

Modelled by R Tait McKenzie, Sculptor.



Obverse



Reverse

EXACT SIZE

side a medallion of Benjamin Franklin done from the Thomas Sully portrait in the possession of the Institute.

3. That the medal should be of gold and have an intrinsic value of about seventy-five dollars.

4. That the sum of five thousand dollars should be provided by him to be held in trust in perpetuity to be a foundation for this medal, and to be known as the Franklin Medal Fund (Founded January 1, 1914, by Samuel Insull, Esq.).

5. That the interest of this fund should be used from time to time in awarding The Franklin Medal to those workers in physical science or technology, without regard to country, whose efforts have, in the judgment of the Institute, done most to advance a knowledge of physical science or its applications.

6. That any excess of income from this fund, beyond such average annual sum as might be deemed necessary by the Institute for the number of medals it is considered best to award, might be used for premiums to accompany the medals.

Mr. Insull said he understood that the Institute would be glad to award, on the average, two Franklin Medals a year. Though this would leave little surplus, he inserted the sixth condition to prevent an undesirable accumulation of the fund.

AT THE STATED MEETING of the Board of Managers, February 11, 1914, the above offer was accepted, and its acceptance was confirmed to Mr. Insull in the following resolutions:

"Resolved, That the Board of Managers of The Franklin Institute of the State of Pennsylvania accept the offer of Mr. Samuel Insull to establish The Franklin Medal, under the conditions named in his letter of December 23, 1913.

"Resolved further, that it is the sense of the Board of Managers of The Franklin Institute that Mr. Insull, in founding this Medal, has rendered a notable service in stimulating workers in Physical Science and Technology and has extended materially the useful activities of the Institute.

"Resolved further, that the thanks of the Board of Managers of the Institute be, and are hereby, extended to Mr. Insull for his generous and greatly appreciated action.

"Resolved further, that an engrossed copy of these resolutions be forwarded to Mr. Insull."

ON MARCH 24, 1914, Mr. Insull forwarded his check for six thousand dollars, and the following deed was duly executed and delivered:

KNOW ALL MEN BY THESE PRESENTS, That THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA FOR THE PROMOTION OF THE MECHANIC ARTS, hereinafter named The Franklin Institute, for and in consideration of the sum of Six Thousand (\$6,000) Dollars to it in hand paid by Samuel Insull, Esq., the receipt whereof is hereby acknowledged, does hereby certify and declare that it holds and will use said sum of money for the following uses, intents and purposes, and upon the following perpetual trusts, that is to say:

1. To expend One Thousand (\$1,000) Dollars, or so much thereof as may be necessary, for the purpose of paying for the design of a medal, and the necessary dies and diploma plates for the purposes hereinafter set forth.

2. To invest and keep invested the balance of said sum, and from the income derived from such investments from time to time to strike off and award medals from said design to workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Board of Managers of said The Franklin Institute have done most to advance our knowledge of physical science or its application. Should the income derived from this fund be more than necessary for the purpose aforesaid, the said The Franklin Institute may, in its discretion, award so much of the surplus, as its Board of Managers deems wise, as premiums to accompany said medals.

3. The fund thus set apart shall be known as "The Franklin Medal Fund" (Founded January 1, 1914, by Samuel Insull, Esq.).

4. The medals to be awarded, as aforesaid, shall be of gold, shall have distinct artistic merit, shall be of the intrinsic value of about seventy-five (\$75) dollars, and shall have on one side thereof a medallion of Benjamin Franklin taken from his portrait by Thomas Sully, now in the possession of the said The Franklin Institute.

IN WITNESS WHEREOF, The said The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts has hereunto set its common corporate seal, attested by the signatures of its President and Secretary, this 28th day of March, A. D. 1914.

[SEAL]

WALTON CLARK,
President.
R. B. OWENS,
Secretary.

CORRESPONDENCE.

NATIONAL ELECTRIC LIGHT ASSOCIATION,
NEW YORK, July 17, 1914.

WALTON CLARK, ESQ.,

The Franklin Institute, Philadelphia, Pa.

DEAR SIR:—

I have much pleasure in forwarding you herewith copy of a resolution adopted at our recent annual convention in Philadelphia.*

Yours truly,

(Signed) T. C. MARTIN,
Secretary.

WHEREAS, Thirty years ago The Franklin Institute, with courage and foresight, organized the First International Electrical Exhibition and the First International Electrical Congress in this country, thereby giving an enormous stimulus to the electrical sciences; and

* Thirty-seventh Convention, held June 1, 2, 3, 4, 5, 1914.

WHEREAS, At this convention it has coöperated to signalize this thirtieth anniversary :

Resolved, That the thanks of the Association be tendered to the Institute for its brilliant coöperation, for the loan and exhibition at the Public Policy meeting of precious Franklin relics ; and

Resolved, That the thanks of the Association be most warmly extended to the Institute, to President Walton Clark, and to Dr. R. B. Owens, Secretary,

(Signed)

T. C. MARTIN,
Secretary

(Signed)

JOS. B. McCALL,
President.

CORRECTION.

IN the article "The Present Status of Airships in Europe," by Jerome C. Hunsaker, June, 1914, issue, Figs. 4, 5, 6, 7, 17, and 18 should have been credited to "Jahrbuch der Luftfahrt" and "Zeitschrift für Flugtechnik und Motorluftschiffahrt," edited and published in Munich, Bavaria, by Ansbert Vorreiter.

LIBRARY NOTES.

Purchases.

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Gifts.

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BOOK NOTICES.

A POPULAR TREATISE ON THE COLLOIDS IN THE INDUSTRIAL ARTS. By Professor Dr. Kurt Arndt. Translated by Nahum E. Katz, B.Sc. Small 8vo, 60 pages and index. The Chemical Publishing Company, Easton, Pa. Price 75 cents.

The author's preface tells us that the book is based on a lecture delivered before a Berlin society, and is intended to present the popular rather than the highly scientific phases of the applied chemistry of colloids. The translator states that the text is from the second German edition and has been supplied with an index, which (we are not astonished to learn) was missing from the original.

The first part of the book, devoted to explanations of terms, gives in simple language the basic facts concerning this comparatively new but actively exploited department of physical chemistry. The ability of the author is a guarantee that the statements are correct. The several topics are well chosen and interestingly treated. The translation is well done, but falls off a little in the later pages. It seems to the reviewer that original German terms are needlessly introduced. Thus the term "reversible" is well established in its technical sense in physical chemistry; it is not necessary to insert after it—in parenthesis—"umkehrbar."

The work is neatly and clearly printed and will be a useful addition to the literature on the subject.

HENRY LEFFMANN.

PRACTICAL IRON FOUNDRING. By Joseph G. Horner, A. M. I. Mech. E. Fourth Edition, thoroughly revised and enlarged. London and New York, Whitaker Company, 1914. 409 pages, illustrations, plates, 12mo. Price 5 shillings.

Since the first edition of this little text-book was issued the art of the iron founder has been almost revolutionized in all its phases. The most notable advances have occurred in the rapid substitution of moulding machines for hand moulding in recent years, and in the practical knowledge gained of the relation between the physical properties and chemical constitution of cast iron as well as of other metallic alloys used by founders.

The book under review treats of these modern methods in a concise manner easily comprehended by students, apprentices, and young engineers, to whom it will be found especially useful. There are 283 illustrations in the body of the book and 15 tables in the Appendix.

This is one of a series of "Practical Handbooks" published by Whitaker and Company; the typography, paper, and binding are good, and the half-tone illustrations, as well as wood-cuts and zinc etchings, are all very well produced.

In conclusion it may be said that the book will appeal more directly to students and founders in Great Britain than in this country, where many advanced methods have been developed that are not alluded to and are apparently not generally known abroad.

A. E. OUTERBRIDGE, JR.

PUBLICATIONS RECEIVED.

Introduction to Organic Chemistry, by John Tappan Stoddard, Professor of Chemistry in Smith College. 419 pages, 5 x 7 inches. Philadelphia, P. Blakiston's Son and Co., no date. Price \$1.50.

U. S. Bureau of Mines, Bulletin 38, *The Origin of Coal*, by David White and Reinhardt Thiessen, with a chapter on the formation of peat by Charles A. Davis. 390 pages, plates, 8vo. Washington, Government Printing Office, 1913.

U. S. Department of Agriculture, Bulletin No. 115, *Professional Paper, Gate Structures for Irrigation Canals*, by Fred C. Scobey, Irrigation Engineer, *Irrigation Investigations*. 61 pages, illustrations, plates, 8vo. *Farmers' Bulletin 602, Production of Clean Milk Prepared in the Dairy Division*. 18 pages, illustrations, 8vo. *Farmers' Bulletin 605, Sudan Grass as a Forage Crop*, by H. N. Vinall, Agronomist, Office of Forage-crop Investigations. 20 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

U. S. Geological Survey, Bulletin 599, *Our Mineral Reserves. How to Make America Industrially Independent*, by George Otis Smith. 48 pages, 8vo. Washington, Government Printing Office, 1914.

Boron in Mineral Waters. H. FONZES-DIACON and FABRE. (*Comptes Rend.*, clviii, 1541.)—The boron content of various mineral waters was investigated by the colorimetric method of Bertrand and Agulhon. It seems to depend to some extent upon the temperature, varying from 0.05 to 0.07 mgm. per litre for the Royat group, and rather less for the Vichy group, to less than 0.005 mgm. in cold mineral waters.

CURRENT TOPICS

Gran-Annular Electric Furnace. Z. JEFFRIES. (*Metal. and Chem. Engin.*, xii, 154.)—The furnace of C. H. Fulton and W. A. Coursen consists essentially of two concentric tubes, of alundum or magnesia, forming an annular chamber for the granulated resistor, viz., kryptol, carbon of the Carbon Company, or graphite of the Åcheson Company. The crucible is stored within the inner tube, of 2 inches diameter. The tubes are imbedded in heavy graphite plates, to which the terminals are attached; outside are powdered magnesia and asbestos. From measurements made in such a furnace with the aid of thermocouples it follows that the three resistor materials mentioned have all a negative temperature coefficient; in the kryptol the resistance dropped from 8.3 ohms to about 1 ohm per cubic inch, as the temperature rose to 1500° C., in the carbon from 5 to 0.5, in the graphite from 1.8 to 0.6; in the last case particularly the small fall of resistance with rising temperature seems to be mainly due to the better contact between the grains consequent upon expansion. The resistance is increased by each heating, owing to the oxidation of some carbon, and the material has to be renewed after about 40 heatings up to 1500° C.

Colloidal Carbon Obtained by a Chemical Method. L. SABATANI. (*Kolloid-Zeits.*, xiv, 29.)—Two grammes of finely powdered sugar are added, gradually during two hours, to 20 c.c. of concentrated sulphuric acid, with constant agitation, and the mixture is allowed to stand at ordinary temperature. After 24 hours the viscous, deep black liquid is poured gradually, with agitation, into 80 c.c. of water, the solution filtered, and dialyzed until free from sulphuric acid. The clear black solution of colloidal carbon thus obtained is very stable; the colloidal particles have an electronegative charge. Gelatinous carbon is obtained by mixing sugar and acid as described above, shaking for two hours, allowing to stand for three to four days at the ordinary temperature, then pouring into a shallow vessel and leaving it together with a vessel of water under a bell-jar. After seven to nine days the viscous solution is converted into a gelatinous mass, which is freed from acid by immersion in water, which is frequently changed. When withdrawn from the water and exposed to air, the jelly gradually shrinks and loses weight. After drying, it forms a very hard, shiny mass, difficult to pulverize, and showing a conchoidal fracture. It swells slightly in water, and dissolves sparingly in alkalies, yielding a colloidal solution.

Interference of Röntgen Rays and Heat Motion. P. DEBYE. (*Ann. d. Physik*, xliii, 1, 49.)—Gives various calculations relating to the theory which indicates that heat motion in the atoms has an essential influence on the interference phenomena observed with Röntgen radiation. The interference intensity decreases exponentially with respect to heat motion (*a*) with increasing angular distance between incident and observation direction, (*b*) with increasing temperature, (*c*) with decreasing wave-length. The exponent of the exponential function vanishes when $T = 0$ with failing null-point energy, and maintains a finite value when a null-point energy exists. The exponent is inversely proportional to the square of the wave-length. The interference intensity is accompanied by a dissipation intensity which is most intense where the interference intensity appears most feeble, and *vice versa*. The course of the phenomena can be calculated when data are forthcoming on the behavior of the specific heat as function of the temperature. A law of similarity holds as with the specific heats of monatomic bodies, according to which the course of temperature is a function of the relation of the characteristic temperature to the temperature of observation.

Advances in Metallurgy of Iron and Steel. SIR ROBERT HADFIELD. (*Presidential Address, Faraday Soc.*, June 11, 1914.)—This address embraced the following subjects: (1) Early metallurgy and alloys of iron and steel. (2) Ancient iron and the Delhi Pillar. (3) Faraday's experiments in 1882. (4) Early workers in scientific metallurgy. (5) French metallurgy in the eighteenth and nineteenth centuries. (6) Value of research. (7) The author's research work. (8) Metallurgy in the middle of the last century. (9) Steel alloys research. (10) Science and practice working together. (11) Development of research during the last fifty years. (12) Special steel alloys. (13) Effect of carbon upon iron. (14) The author's experiments on alloy tool steel. (15) Tool steel of lower carbon percentage. (16) The great work of Ledebur. (17) Allotropic theory. (18) The author's papers on alloys of iron. (19) Thermal treatment. (20) Low-temperature experiments in Great Britain and America. (21) Field for research. (22) The non-magnetic and magnetic conditions of manganese steel. (23) Melting-points. (24) Microscopy (Sorby's work as the originator of metallography). (25) Percy's work. (26) The art of scientific discovery. (27) Why research work is so valuable. (28) The work of the National Physical Laboratory. (29) Past progress in metallurgy. (30) The scope of the University. (31) The Faraday Society.

Instruments for High-frequency Currents and Voltages. W. H. ECCLES. (*Electrician*, lxxii, 1044.)—A description of a simple hot-wire ammeter of quick period, a very sensitive electrometer of simple construction, and a convection galvanometer. All have been employed successfully by the author for high-frequency work.

Sun-power Plants. ANON. (*Amer Mach.*, xli, No. 7, 270.)—In a paper presented to the Institution of Engineers and Ship-builders, dealing with the commercial utilization of sun-power, it is pointed out that the uses to which sun-power plants can be put are unlimited, but probably from their very nature they will be chiefly used, to begin with, for irrigation purposes. In Egypt alone 100,000 men are employed all the year round in filling watercourses with buckets of water from the Nile. These men will find more useful and profitable scope for their labor, and, as prejudice is gradually dispelled, industries will be started in the tropics that were never even dreamed of. The Nile Valley, rich in everything but nitrates, uses 70,000 tons of artificial fertilizers per annum. Here, then, is a profitable field for cheap power, with the supply and demand in the same place. The manufacture of artificial ice is another industry that suggests itself as being suitable for sun-power, and could there be a more rational source of heat for all evaporators for whatever purpose? The synthetic production of hydrocarbon gas from calcium carbide, which could be produced at small cost in electrical furnaces, using sun plants, gives a means of getting illuminating gas apart from coal.

Canadian Pure Food Regulations. ANON. (*Chem. Trade J.*, June 6, 1914.)—A Canadian Order-in-Council lays down certain regulations made in accordance with the provisions of Section 26 of the Adulteration of Foods Act. The regulations governing the employment of preservatives apply to foods intended for domestic consumption. Foods intended for export may contain certain preservatives, provided that, both in specific character and in amount, such preservatives do not conflict with regulations in force in the country to which export is made.

It is forbidden to add any preservative whatever to milk, or any other than the following to foods especially intended for the use of infants or invalids: Common salt, salpetre, woodsmoke, vinegar, acetic acid, spices, or alcohol. These preservatives, which are included in Class I, may be used without declaration of their presence, provided that such use does not conflict with any other statutory regulation.

Class II refers to preservatives which may be used until further notice, provided that no more than one kind of preservative substance, named in the list, shall be added to any one kind of food, or to any mixture of two or more kinds of food; that the amount of preservative shall not exceed the maximum amount named, and that the presence of the preservative shall be declared on the label.

Toleration of the use of this class of preservative is dependent upon the fact that available evidence concerning their physiological action is not considered sufficient to prove that under the prescribed regulations they are harmful to health in such a degree as to bring them under Section 3 (f) of the Adulteration Act, which reads as follows: "Food shall be deemed to be adulterated within the meaning

of this act if it contains any added poisonous ingredient, or any ingredient which may render such an article injurious to the health of the persons or cattle consuming it." Should satisfactory evidence of the harmfulness to health of any of the preservatives named in Class II be forthcoming, such preservatives would immediately fall under the condemnation of the Adulteration Act, and foods containing such preservatives would be declared to be adulterated.

(1) Boric acid (boracic acid) or borax. Limit: 1 part in 400 in cream; 1 part in 200 in butter and other foods. (2) Benzoic acid (sodium benzoate). Limit: 1 part in 1000 parts. (3) Salicylic acid. Limit: 1 part in 5000 parts. (4) Sulphurous acid (sodium, potassium or calcium bisulphites). Limit: 1 part in 10,000 parts in beverages; 1 part in 2000 parts in solid foods. (5) Saccharin. Limit: 1 part in 1500 parts in beverages; 1 part in 700 parts in solid foods. (This substance shall not be used to take the place of sugar in any food in which sugar is employed as a source of nutriment, or for its feeding value. Where sugar is used only as a sweetener, saccharin may replace it under the conditions defined above.)

The following preservative substances, included in Class III, are prohibited from use in foods: Formaldehyde, (formalin), betanaphthol, abrastol (asaprol), hydrofluoric acid, fluorides, fluo-borates, fluo-silicates, or other fluorine compounds.

New Chemists' Slide Rule. H. R. LEE. (*Metall. and Chem. Engin.*, xii, 201.)—This is a description of a new type of slide rule designed to meet the needs of chemists engaged in commercial analysis. The regular or front side of the rule shows the molecular symbols of forty-six salts and ten acids and bases on the A scale of the frame, and a parallel list of these on the B scale of the slide. On the back appear the symbols of forty-two elements and thirty-seven oxides in place of the usual A scale on the frame, and a parallel list of these on the BI scale of the slide. The C and D scales on the front and the CI and DI scales on the back are graduated numerically, as is usual on the engineers' slide rule. The results obtained with the rule are of as high order of accuracy as the chemical work, which precedes its use, is usually expected to be.

The Corrosion of Aluminum. ANON. (*Metal Ind.*, xii, No. 8, 345.)—Recent researches prove that aluminum is subject to two kinds of corrosion: one resulting from a uniform attack all over the surface, while the other is localized in scales and spots. The second case is generally produced on metal which has been mechanically worked by drawing or rolling. As in the case of iron, it seems that the metal must be exposed to air and moisture at the same time, for one alone will not produce it. Carbonic acid is a leading element in the corrosion. Worked aluminum scales off in the direction in which the mechanical action has been carried out.

Use of Gold in Ceramics. A. GRANGER. (*La Céramique*, 1912, 262, and 1913, 3.)—Gold is used on pottery either for gilding or as a coloring agent in glazes. Its value for gilding lies in its resistance to oxidation and the fineness of the layer which can be produced, for which reason it is not an expensive stain. A flux is employed in application, and mercurous oxide reduces the amount of gold required. A mixing of the composition: 30 parts by weight of precipitated gold, 15 of black mercurous oxide, 2.5 of basic bismuth nitrate, and 0.3 of melted borax, is recommended; the addition of 3 parts of silver carbonate to this produces a greenish tint. After firing in the muffle the gold has a matt surface, and must be polished with bloodstone or agate. A cheaper process, which does not require polishing after the burn, is the use of "Glanzgold" or "Meissen-gold," a preparation of gold solution with an organic medium such as turpentine, lavender oil, and balsam or resin. As a coloring agent in glazes, gold produces shades from violet to purple and red, of which the best known is purple of Cassius, a lake of precipitated gold with a metallic hydroxide, preferably that of tin, which was formerly regarded as a definite compound. The presence of ammonia or alum in the stannous chloride solution produces shades from dark to rose-purple, and the tint may be further modified by the substitution of antimony or magnesia for tin. Choice of flux materially influences the color; various recipes are given containing lead oxide, borax, or feldspar; and kaolin may be used as a base for the lake. In lead glazes 1 part of gold in 1000 parts of glaze powder will produce a deep red glaze; and in leadless glazes, 1 in 10,000. An under glaze stain can be produced from 50 parts of pegmatite, 50 of alumina, and 1 of gold chloride. Gold may be applied under a glaze on places previously moistened with gum tragacanth solution.

Base-metal Thermocouples. O. L. KOWALKE. (*Amer. Electrochem. Soc. Trans.*, xxiv, 377.)—Investigations were made on various thermocouples which have recently come into use for industrial purposes, and are made of metals, such as iron and nickel and alloys of nickel, cobalt, etc. The object was to determine how the electromotive force of the couples varied with the temperature, and how its constancy was affected by successive heatings and coolings and by exposure to various temperatures for extended periods of time. The couples tested were all compared with a Pt and Pt-Rh couple which had been standardized by a similar couple certified by the Bureau of Standards. From the experiments made it seems possible to obtain a base-metal couple which is reasonably homogeneous and will give indications of temperature which are sufficiently constant to meet the requirements of the industries. For measurements of a greater accuracy than within 25° a higher grade of instrument is required. Sufficient care is not exercised in thoroughly annealing couples. Once the couple has attained its permanent structure there is not much change in the electromotive force.

The Atmospheric Obscurity of 1912-13. J. MAURER and C. DORNO. (*Meteorolog. Zeitschr.*, xxxi, 49.)—At the beginning of 1913 the president of the Radiation Commission of the International Meteorological Committee, J. Maurer, issued a circular letter to meteorological institutes, asking that observational material on the remarkable atmospheric obscurity of 1912 should be sent to him. The paper is a report on the results obtained on working up the material received in response to the letter.

The general cause of the obscurity is attributed to the volcanic eruption of Katmai, in Alaska, on June 6, 1912; for successive phases of obscurity can be traced from place to place in relation to the time which had elapsed since the eruption. The first phase began on June 6 in the form of high, clear clouds which travelled from WNW. to ESE. This phase reached Zürich on June 23rd, Egypt on June 28th, and it was not sufficiently intense to affect the records of Campbell-Stokes sunshine recorders. The maximum intensity of this phase at any place usually occurred at one to three weeks after the commencement. The second phase, which was similar in character to the first, was observed on Mount Wilson on June 21st. It reached Algiers on July 11th and Egypt on August 8th. The third phase was noted in Washington to commence from July 19th to 26th, and it arrived in Egypt at the end of August, but this phase was lacking altogether at some stations, while at others the maximum of disturbance occurred during its course. The fourth phase spread from America to Egypt during the month of September. The end of the disturbance was noted in October at most places. The phenomena appeared to be confined to that part of the northern hemisphere lying between the polar circle and the Tropic of Cancer, but it is not ascertained whether they extended completely round the globe, within those limits.

Copper Production in Russia. ANON. (*The Metal Ind.*, xii, No. 7, 292.)—The production of copper in the Caucasus in 1913 was 9222 tons, as compared with 10,368 tons in 1912. One of the three companies is erecting a concentration plant, part of which was completed and in operation before the end of 1913. A new ropeway was also completed, and other improvements were made. The company hopes to maintain production at 400 to 500 tons per month. A new plant was erected by another firm at its copper deposits at Kwartshana, in the province of Batum, and it is reported that considerable ore there is ready for treatment as soon as the blast furnace smelting works are completed.



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THE THUNDERSTORM AND ITS PHENOMENA.*

BY

W. J. HUMPHREYS, C.E., Ph.D.,

Professor of Meteorological Physics, U. S. Weather Bureau, and George Washington University.

Introduction.—A thunderstorm, as its name implies, is a storm characterized by thunder and lightning, just as a dust storm is one characterized by a great quantity of flying dust. But the dust is never in any sense the cause of the storm that carries it along, nor, so far as known, does either thunder or lightning have any influence on the course—genesis, development, or termination—of even those storms of which they form, in some respects, the most important features. No matter how impressive or how terrifying these phenomena may be, they never are anything more than mere incidents to or products of the peculiar storms they accompany, as will be made clear by what follows. In short, they are never in any sense either storm-originating or storm-controlling factors.

Origin of Thunderstorm Electricity.—A knowledge, or at least a good working hypothesis, of how the great amount of electricity incident to thunderstorms is generated, is absolutely essential to their logical explanation; that is, to a clear understanding of the probable interrelations between their many phenomena.

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Fortunately such an hypothesis, or theory, rather, since it is abundantly supported by observations and by laboratory experiments, is available as a result of work done on this subject in India by Dr. G. C. Simpson,¹ of the Indian Meteorological Department.

Dr. Simpson's observations, just referred to, were obtained at Simla, India, at an elevation of about 7000 feet above sea level, and covered all of the monsoon seasons, that is, roughly, April 15 to September 15, of 1908 and 1909. He also obtained observations of the electrical conditions of the snow at Simla during the winter of 1908-9.

A tipping-bucket rain gauge gave an automatic continuous record of the rate and time of rainfall, while a Bendorf² self-registering electrometer marked the sign and potential of the charge acquired during each two-minute interval. A second Bendorf electrometer registered the potential gradient near the earth, and a coherer of the type used in radiotelegraphy registered the occurrence of each lightning discharge.

All obvious sources of error were examined and carefully guarded against. Hence it would seem that the conclusions drawn from the thousands of observations given in the memoir are fully justified; and especially so since several independent series of similar observations made at different times, by different people, and at places widely separated, have given confirmatory results in every case. Simpson's records show that—

(1) The electricity brought down by the rain was sometimes positive and sometimes negative.

(2) The total quantity of positive electricity brought down by the rain was 3.2 times greater than the total quantity of negative electricity.

(3) The period during which positively charged rain fell was 2.5 times longer than the period during which negatively charged rain fell.

(4) Treating charged rain as equivalent to a vertical current of electricity, the current densities were generally smaller than 4×10^{-15} ampères per square centimetre; but on a few occasions greater current densities, both positive and negative, were recorded.

(5) Negative currents occurred less frequently than positive currents, and the greater the current density the greater the preponderance of the positive currents.

(6) The charge carried by the rain was generally less than 6 electrostatic units per cubic centimetre of water, but larger charges were occasionally recorded, and in one exceptional storm (May 13, 1908) the negative charge exceeded 19 electrostatic units per cubic centimetre.

(7) As stated in paragraph (3), positive electricity was recorded more frequently than negative, but the excess was the less marked the higher the charge on the rain.

(8) With all rates of rainfall positively charged rain occurred more frequently than negatively charged rain, and the relative frequency of positively charged rain increased rapidly with increased rate of rainfall. With rainfall of less than about 1 millimetre in two minutes, positively charged rain occurred twice as often as negatively charged rain, while with greater intensities it occurred fourteen times as often.

(9) When the rain was falling at a less rate than about 0.6 millimetre in two minutes, the charge per cubic centimetre of water decreased as the intensity of the rain increased.

(10) With rainfall of greater intensity than about 0.6 millimetre in two minutes the positive charge carried per cubic centimetre of water was independent of the rate of rainfall, while the negative charge carried decreased as the rate of rainfall increased.

(11) During periods of rainfall the potential gradient was more often negative than positive, but there were no clear indications of a relationship between the sign of the charge on the rain and the sign of the potential gradient.

(12) The data do not suggest that the negative electricity occurs more frequently during any particular period of a storm than during any other.

Concerning his observation on the electrification of snow Dr. Simpson says:

So far as can be judged from the few measurements made during the winter of 1908-9 it would appear that:

(1) More positive than negative electricity is brought down by snow in the proportion of about 3.6 to 1.

(2) Positively charged snow falls more often than negatively charged.

(3) The vertical electric currents during snowstorms are on the average larger than during rainfall.

(4) The charge per unit mass of precipitation is larger during snowfall than during rainfall.

While these observations were being secured a number of well-devised experiments were made to determine the electrical effects of each obvious process that takes place in the thunderstorm.

Freezing and thawing, air friction, and other things were tried, but none produced any electrification. Finally, on allowing drops of *distilled* water to fall through a vertical blast of air of sufficient strength to produce some spray, positive and important results were found, showing:

(1) That breaking of drops of water is accompanied by the production of both positive and negative ions.

(2) That three times as many negative ions as positive ions are released.

Now, a strong upward current of air is one of the most conspicuous features of the thunderstorm. It is always evident in the turbulent cauliflower heads of the cumulus cloud, the parent, presumably, of all thunderstorms. Besides, its inference is compelled by the occurrence of hail, a frequent thunderstorm phenomenon, whose formation requires the carrying of raindrops and the growing hailstones repeatedly to cold and therefore high altitudes. And from the existence of hail it is further inferred that an updraft of at least 8 metres per second must often occur within the body of the storm, since, as experiment shows, it requires approximately this velocity to support the larger drops, and even a greater velocity to support the average hailstone.

Experiment also shows that rain cannot fall through air of ordinary density whose upward velocity is greater than about 8 metres per second, or itself fall with greater velocity through still air; that in such a current, or with such a velocity, drops large enough, if kept intact, to force their way down, or, through the action of gravity, to attain a greater velocity than 8 metres per second with reference to the air, whether still or in motion, are so blown to pieces that the increased ratio of supporting area to total mass causes the resulting spray to be carried aloft or left behind, together with, of course, all original smaller drops. Clearly, then, the updrafts within a cumulus cloud frequently must break up at about the same level innumerable drops which, through coalescence, have grown beyond the critical size, and

thereby, according to Simpson's experiments, produce electrical separation within the cloud itself. Obviously, under the turmoil of a thunderstorm, its choppy surges and pulses, such drops may be forced through the cycle of union (facilitated by any charges they may carry) and division, of coalescence and disruption, from one to many times, with the formation on each at every disruption, again *according to experiment*, of a correspondingly increased electrical charge. The turmoil compels mechanical contact between the drops, whereupon the charges break down the surface tension and insure coalescence. Hence, once started, the electricity of a thunderstorm rapidly grows to a considerable maximum.

After a time the larger drops reach, here and there, places below which the updraft is small—the air cannot be rushing up everywhere—and then fall as positively charged rain, because of the processes just explained. The negative electrons in the meantime are carried up into the higher portions of the cumulus, where they unite with the cloud particles and thereby facilitate their coalescence into negatively charged drops. Hence, the heavy rain of a thunderstorm should be positively charged, as it almost always is, and the gentler portions negatively charged, which also usually is the case.

Such in brief is Dr. Simpson's theory of the origin of the electricity in thunderstorms, a theory that fully accounts for the facts of observation and in turn is itself abundantly supported by laboratory tests and simulative experiments.

If this theory is correct, and it seems well founded, it must follow that the one essential to the formation of the giant cumulus cloud, namely, the rapid uprush of moist air, is also the one essential to the generation of the electricity of thunderstorms. Hence, the reason why lightning seldom if ever occurs except in connection with a cumulus cloud is understandable and obvious. It is simply because the only process that can produce the one is also the process that is necessary and sufficient for the production of the other.

The Violent Motions of Cumulus Clouds.—From observations, and from the graphic descriptions of the few balloonists who have experienced the trying ordeal of passing through the heart of a thunderstorm, it is known that there is violent vertical motion and much turbulence in the middle of a large cumulus

cloud, a fact which, so far as it relates to the theory alone of the thunderstorm, it would be sufficient to accept without inquiring into its cause. However, to render the discussion more nearly complete, it perhaps is worth while, since it is a mooted question, to inquire what the probable cause of the violent motions in large cumulus clouds really is—motions which, in the magnitude of their vertical components and degree of turmoil, are never exhibited by clouds of any other kind nor met with elsewhere by either manned, sounding, or pilot balloons.

It has been shown by von Bezold³ that sudden condensation from a state of supersaturation, and also sudden congelation of undercooled cloud droplets, would, as a result of the heat thus liberated, cause an equally sudden expansion of the atmosphere, and thereby turbulent motions analogous to those observed in large cumuli. However, as von Bezold himself points out, it is not evident how either the condensation or the freezing could suddenly take place throughout a cloud volume great enough to produce the observed effects. Besides, these eruptive turmoils, whatever their genesis, undoubtedly originate and run their course in regions already filled with cloud particles in the presence of which no appreciable degree of supersaturation can occur. Hence the rapid uprush and the violent turbulence in question obviously must have some other cause; and this we shall find in the difference between the actual temperature gradient of the surrounding atmosphere and the adiabatic temperature gradient of the saturated air within the cloud itself.

Consider a warm summer afternoon, temperature 30° C., say, and assume the dew point to be 15° C. Now, the adiabatic decrease of temperature of non-saturated air is about 1° C. per 100 metres change in elevation, and therefore, under the assumed conditions, vertical convection of the surface air causes condensation to begin at an elevation of approximately 1.5 kilometres. From this level, however, so long as the cloud particles are carried up with the rising air, the rate of temperature decrease, for at least a couple of kilometres, is much less—at first about one-half the previous rate. After a considerable rise above the level of initial condensation, half a kilometre, say, the raindrops have so increased in size as to lag behind the upward current and even to drop out, while, at the same time, the amount of moisture condensed per degree fall of temperature grows rapidly less. Hence,

for both reasons—because the heat of the condensed water is no longer available to the air from which it was condensed, the drops having been left behind, and because but little latent heat is to be had from further condensation, there being but little water vapor left—the rate of temperature decrease again approaches the adiabatic gradient of dry air, or 1° C. per 100 metres change of elevation.

Obviously, then, for some distance above the level at which condensation begins to set free its latent heat, the temperature of the rising mass of moist air departs farther and farther from the temperature of the surrounding atmosphere at the same level, and therefore its buoyancy for a time as steadily increases. But, of course, as explained above, this increase of buoyancy does not continue to any great altitude.

In the lower atmosphere continuous and progressive convection builds up the adiabatic gradient so gradually that no great difference between the temperature of the rising column and that of the adjacent atmosphere is anywhere possible. Hence, under ordinary conditions, the uprush in this region is never violent. But whenever the vertical movement of the air brings about a considerable condensation it follows, as above explained, that there is likely to be an increase in its buoyancy, and hence a more or less rapid upward movement of the central portion, like air up a heated chimney, and for the same reason, together with, because of viscosity, a rolling and turbulent motion of the sides, of the type so often seen in towering cumulus clouds. Obviously, too, the uprushing columns of air must ascend somewhat beyond its point of equilibrium, and then, because slightly undercooled, correspondingly drop back.

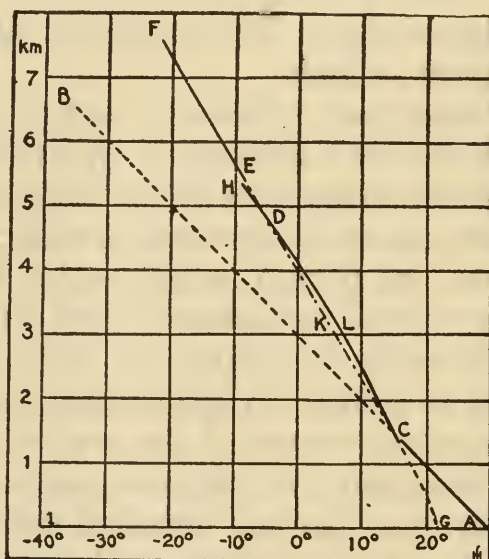
Fig. 1, based upon approximately average conditions, illustrates the points just explained. The elevation is in kilometres and the temperature in degrees centigrade.

AB is the approximate temperature gradient for non-saturated air, about 1° C. per 100 metres change in elevation. *GCKDEF* is the supposed temperature gradient before convection begins, or a decrease, in accordance with observations, of 6° C., approximately, per kilometre increase of elevation, except near the surface, where the temperature decrease, before convection has begun, ordinarily is less rapid.

As convection sets in, the temperature decrease near the

surface soon approximates the adiabatic gradient for dry air, and this condition extends gradually to greater altitudes, till, in the assumed case, condensation begins at the level *C*, or where the temperature is 15° C. Here the temperature decrease, under the assumed conditions, suddenly changes from 10° C. per kilometre increase of elevation to rather less than half that amount, but slowly increases with increase of altitude and consequent decrease of temperature. At some level, as *L*, the temperature difference between the rising and the adjacent air is a maximum. At *D* the temperature of the rising air is the same as that of the air

FIG. I.

Temperature gradients within (*CLD*) and without (*CKD*) cumulus clouds.

adjacent, but its momentum presumably carries it on to some such level as *H*. Within the rising column, then, the temperature gradient is approximately given by the curve *ACLDHE*, while the temperature gradient of the surrounding air is given by the curve *ACKDEF*.

The cause, therefore, of the violent uprush and turbulent condition within large cumulus clouds is, presumably, the difference between the temperature of the inner or warmer portions of the cloud itself and that of the surrounding atmosphere at the same level, as indicated by their respective temperature gradients *CLD* and *CKD*. Clearly, too, while some air must flow into the condensation column all along its length, the greatest pressure

difference, and, therefore, the greatest inflow, obviously is at its base. After the rain has set in, however, this basal inflow is from immediately in front of the storm, and necessarily so, as will be explained later.

Convictional Instability.—Rapid vertical convection of humid air, as we have seen, is essential to the production of the cumulus cloud and, therefore, to the generation of the thunderstorm. Hence it is essential to consider the conditions under which the vertical temperature gradient necessary to this convection can be established. These are:

1. Strong surface heating, especially in regions of light winds; a frequent occurrence.

The condition that the winds be light is not essential or, perhaps, even favorable to the genesis of all thunderstorms—only the local or heat variety, and favorable to these simply because heavy winds tend to prevent the formation of isolated rising columns of air, the progenitor of this particular type of storm.

2. The overrunning of one layer of air by another at a temperature sufficiently lower to induce convection, well-nigh the sole cause of ocean thunderstorms and also of frequent occurrence on land.

3. The underrunning and consequent uplift of a saturated layer of air by a denser layer; a frequent occurrence to a greater or less extent, and presumably, therefore, at least an occasional one of sufficient magnitude to produce a thunderstorm.

Here the underrunning air lifts both the saturated layer and the superincumbent unsaturated layer, and thereby forces each to cool adiabatically. But as both layers are lifted equally while, because of the latent heat of condensation, the saturated layer cools much slower than the dry, it follows that a sufficient mechanical lift of a saturated layer of air would establish between it and the non-saturated layer above a superadiabatic temperature gradient and thereby produce local convection, cumulus clouds, and, perhaps, a thunderstorm.

Periodic Recurrence of Thunderstorms.—While thunderstorms may occur at any hour of any day they nevertheless have three distinct periods of maximum occurrence: *a*, daily, *b*, yearly, and *c*, irregularly cyclic. Each maximum depends upon the simple facts that the more humid the air and the more rapid the local vertical convections the more frequent and also the more intense

the thunderstorms, for the obvious reason that it is rapid vertical convection of humid air that produces them.

Daily Land Period.—Vertical convection of the atmosphere over land areas is most pronounced when the surface is most heated; that is, during afternoons. Hence the hours of maximum frequency of inland or continental thunderstorms are, in most places, 2 to 4 P.M.

Daily Ocean Period.—Because of evaporation and of the high specific heat of water the surface temperature of the ocean increases but little during the day, and because of convection it decreases but slightly at night. Indeed, the diurnal temperature range of the ocean surface usually is but a small fraction of 1° C., while that of the atmosphere at from 500 to 1000 metres elevation is several fold as great.⁴ Hence those temperature gradients over the ocean that are favorable to rapid vertical convection are most frequent during the early morning hours, and, therefore, the maximum of ocean thunderstorms usually occurs between midnight and 4 A.M.

Yearly Land Period.—Just as inland thunderstorms are most frequent during the hottest hours of the day, so too, and for the same reason, they are, in general, most frequent over the land during the hottest months of the year, or, rather, during those months when the amount of surface heating and, therefore, the vertical temperature gradient is a maximum.

Hence, in middle latitudes, where there are no late spring snows to hold back the temperatures, the month of maximum frequency often is June. In higher latitudes, where the strong surface heating is more or less delayed, the maximum occurs in July or even August.

Yearly Ocean Period.—Over the oceans, on the other hand, temperature gradients favorable to the genesis of thunderstorms, and, therefore, the storms themselves, occur most frequently during the winter and least frequently during the summer. This is because the temperature of the air at some distance above the surface, being largely what it was when it left the windward continent, greatly changes from season to season, while that of the water, and, of course, the air in contact with it, changes but little through the year. That is, over the oceans the average decrease of temperature with increase of elevation obviously is least and,

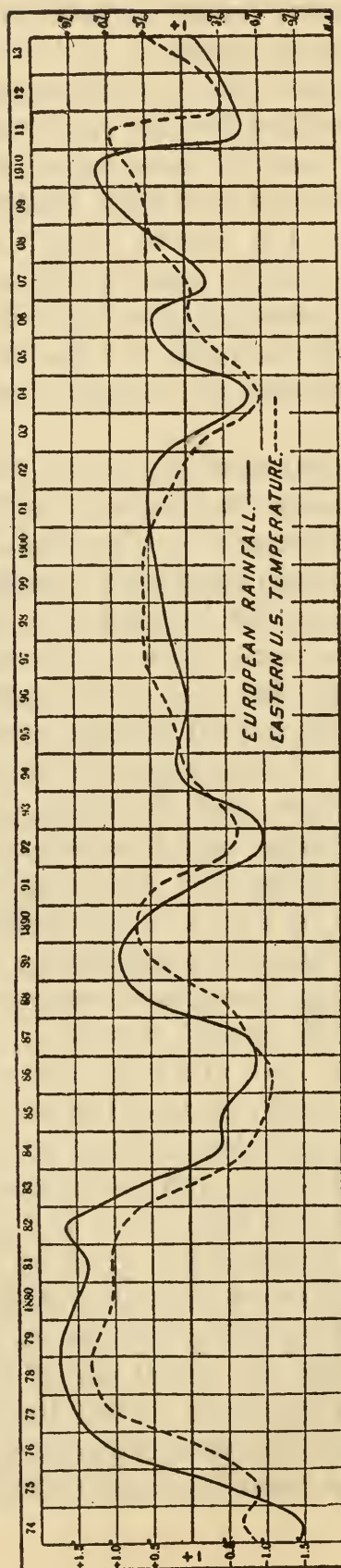
therefore, thunderstorms fewest in summer, and greatest, with storms most numerous, in winter.

Cyclic Land Period.—Since thunderstorms are accompanied by rain and since over land they are most numerous during summer, it would appear that they must occur most frequently either in warm or in wet years and least frequently in cold or in dry years. Further, if it should happen, as it actually does, that, for the earth as a whole, warm years are also wet years and dry years cold years, it would appear logically certain that, for the entire world, the maximum number of thunderstorms must belong to the years that are wet and warm and the minimum to those that are cold and dry.

A complete statistical examination of these statements is not possible, owing to the fact that meteorological data are available for only portions of the earth's surface and not for the whole of it. Nevertheless, well-nigh conclusive data do exist. The annual rainfall, for instance, to the leeward of a large body of water obviously must bear the same relation to the annual average windward temperature that the total annual precipitation over the entire world does to the annual average world temperature. In each case the amount of evaporation or amount of water vapor taken into the atmosphere, and, therefore, the amount of subsequent precipitation, clearly must increase and decrease with the temperature. An excellent test and complete support of this deduction is furnished by Fig. 2, in which the full line represents the smoothed annual European precipitation,⁵ and the dotted line smoothed annual average American temperatures.

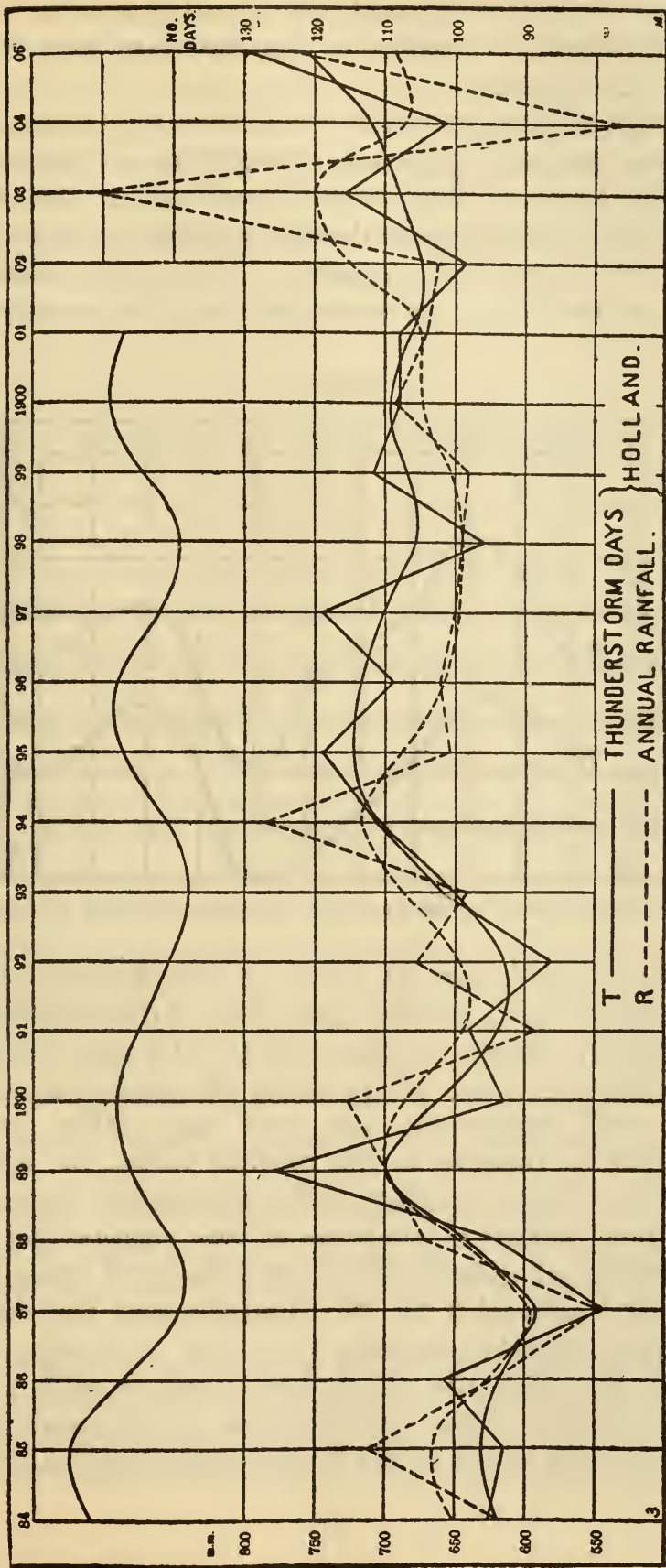
Beyond a reasonable doubt, therefore, for the world as a whole, warm years are wet and cold ones are dry. Hence, as above stated, it is practically certain that the maxima of thunderstorms occur during years that are wet, or warm, if we prefer, for the two are synchronous, and the minima during years that are dry, or cold. A partial and, so far as it goes, a confirmatory statistical test of this conclusion is given by Fig. 3. The lower group of curves is based on an exhaustive study by Dr. von Gulik⁶ of thunderstorms and lightning injuries in Holland. The continuous zigzag line gives the actual annual number of thunderstorm days and the continuous curved line the same numbers smoothed. The broken lines give, respectively, the actual and the smoothed values of the annual average precipitation. The upper

FIG. 2.



Relation of European rainfall to eastern United States temperature.

FIG. 3.

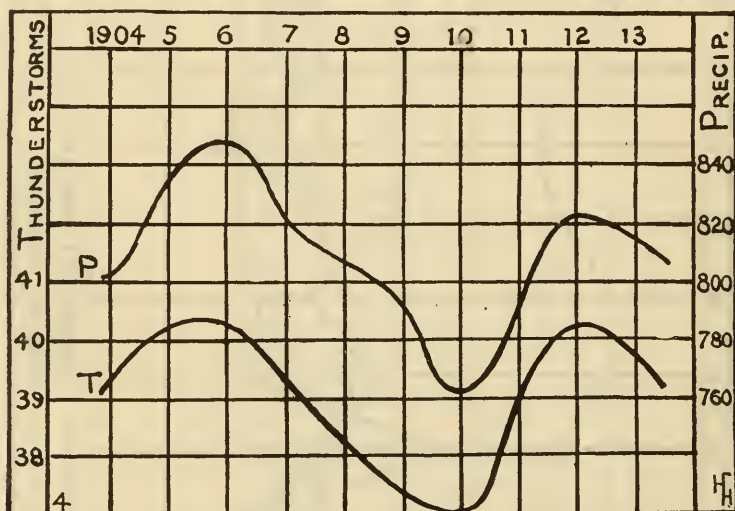


Relation of annual number of thunderstorm days to total annual precipitation—Holland.

curve represents the variations in the smoothed number of destructive thunderstorms⁷ (number of thunderstorm days not readily available) in Germany.

The original data on which this last curve is based indicate a continuous and rapid increase of thunderstorm destructiveness. Presumably, however, this feature is real only to the extent that the country has become more densely populated and more thickly studded with destructible property. At any rate, this element has been omitted from the curve and only the variation factor retained.

FIG. 4.



Relation of annual number of thunderstorms, T , to total precipitation, P —United States.

It will be noted that the curve of thunderstorm frequency for all Holland closely parallels the curve of thunderstorm injury in all Germany. Hence, it seems safe to infer that the frequency of thunderstorms varies pretty much the same way over both countries, and, presumably, also over many other portions of Europe; that is, roughly as the rainfall varies, or, considering the world as a whole, roughly as the temperature varies.

Additional statistical evidence of the relation between the annual number of thunderstorms and the total annual precipitation, kindly assembled by the Climatological Division of the United States Weather Bureau, P. C. Day in charge, is shown by Fig. 4, in which the upper line gives, in millimetres, the smoothed average annual precipitations of 127 stations widely scattered over the whole of the United States, and the lower line

the smoothed average annual number of thunderstorms at these same stations. It was thought at first that this relation might differ greatly for those portions of the United States whose climates are radically dissimilar, and for this reason the stations east of the one hundredth meridian provisionally were classed separately from those west of it; but the results for the two sections, being substantially alike, show that for this purpose their division is entirely unnecessary.

As will be seen from the figure, the statistics of only the past ten years have been used. This is because the annual number of such storms reported rapidly decreases from 1904 back to about 1890. Indeed, the annual number of thunderstorms reported per station during the past ten years is almost double the annual number per station (practically the same stations) from 1880 to 1890. The transition from the smaller to the larger number was due in great measure, doubtless, to an alteration in station regulations that changed the official definition of a thunderstorm from "thunder *with* rain" to "thunder *with* or *without* rain." This, however, does not account for the fact that from 1890 to 1904 the average annual number of thunderstorms reported per station increased, at a nearly constant rate, almost 100 per cent. Either the storms did so increase, which seems improbable, or else there was, on the average, an increase of attention given to this particular phenomenon. At any rate, so continuous and so great an increase in the average number of thunderstorms can hardly be accepted without abundant confirmation, and for this reason the earlier thunderstorm records provisionally have been rejected.

Obviously a much closer relation between the number of thunderstorms and total precipitation would hold for some months and seasons than for others, but no such subgrouping of the data has been made, though, presumably, it would give interesting results. The whole purpose of this portion of the study was to arrive at some definite idea in regard to the cyclic change of thunderstorm frequency, to see with what other meteorological phenomena this change is associated, and, if possible, to determine its cause.

Now it is well known that the average temperature of the world as a whole follows in general the sun-spot changes, in the sense that the greater the number of spots the lower the temperature and the smaller the number of spots the higher the tempera-

ture. This regular relation, however, often is greatly modified⁸ by the presence in the high atmosphere of volcanic dust, one invariable effect of which is a lower average temperature. Hence, the warm and the cold periods are irregularly cyclic, and also irregular in intensity. Hence, also, the annual amount of precipitation, the frequency of thunderstorms, and many other phenomena must perforce undergo exactly the same irregular cyclic variation.

As already stated, the statistical evidence bearing on these conclusions neither is nor can be complete, but the deductions are so obvious and the statistical data already examined so confirmatory that but little doubt can exist of their general accuracy.

Cyclic Ocean Period.—The record of thunderstorms over the oceans is not sufficiently full to justify any conclusions in regard to their cyclic changes. Possibly, as in the yearly and the daily periods, the ocean cyclic period may be just the reverse of that of the land, but this is not certain.

Geographic Distribution.—The geographic distribution of the thunderstorm may safely be inferred from the fact that it is caused by the strong vertical convection of humid air. From the nature of its formation one would assume, and the assumption is supported by observation, that the thunderstorm must be rare beyond either polar circle, especially over Greenland and over the Antarctic continent, rare over great desert regions wherever situated, and on the other hand, increasingly abundant with increase of temperature and humidity, and, therefore, in general, most abundant in the more rainy portions of the equatorial regions. The east coast of South America from Pernambuco to Bahia is said to be an exception.

Pressure and Temperature Distribution.—In illustrating the occurrence of thunderstorms with reference to the disposition of isobars and isotherms, or the distribution of atmospheric pressure and temperature, typical weather maps of the United States,* Figs. 5–19, have been used, not because the thunderstorms of this country are different in any essential particular from those of other countries, but chiefly as a matter of convenience in making the drawings. To facilitate their study each of the several types

* The author wishes to acknowledge the courteous coöperation of the Forecast Division, U. S. Weather Bureau, in selecting maps typical of thunderstorm conditions in the United States.

discussed is illustrated with three consecutive maps. The first shows the 12-hour antecedent conditions, the second the particular pressure-temperature distribution in question, and the third the 12-hour subsequent conditions.

In these figures the isobars, in corrected inches of mercury, and the isotherms, in Fahrenheit degrees, are marked by full and by dotted lines, respectively. The legend "LOW" is written over a region from which, for some distance in every horizontal direction, the pressure increases. Similarly, the legend "HIGH" applies to a region from which, in every direction, the pressure decreases. The arrows, as is customary on such maps, fly with the wind, while the state of weather is indicated by the usual U. S. Weather Bureau symbols.

Obviously, the key to the geographic distribution of thunderstorms, vertical convection of humid air, is also the key to their location with reference to the existing distribution of barometric pressure. From this standpoint the places of their most frequent occurrence are:

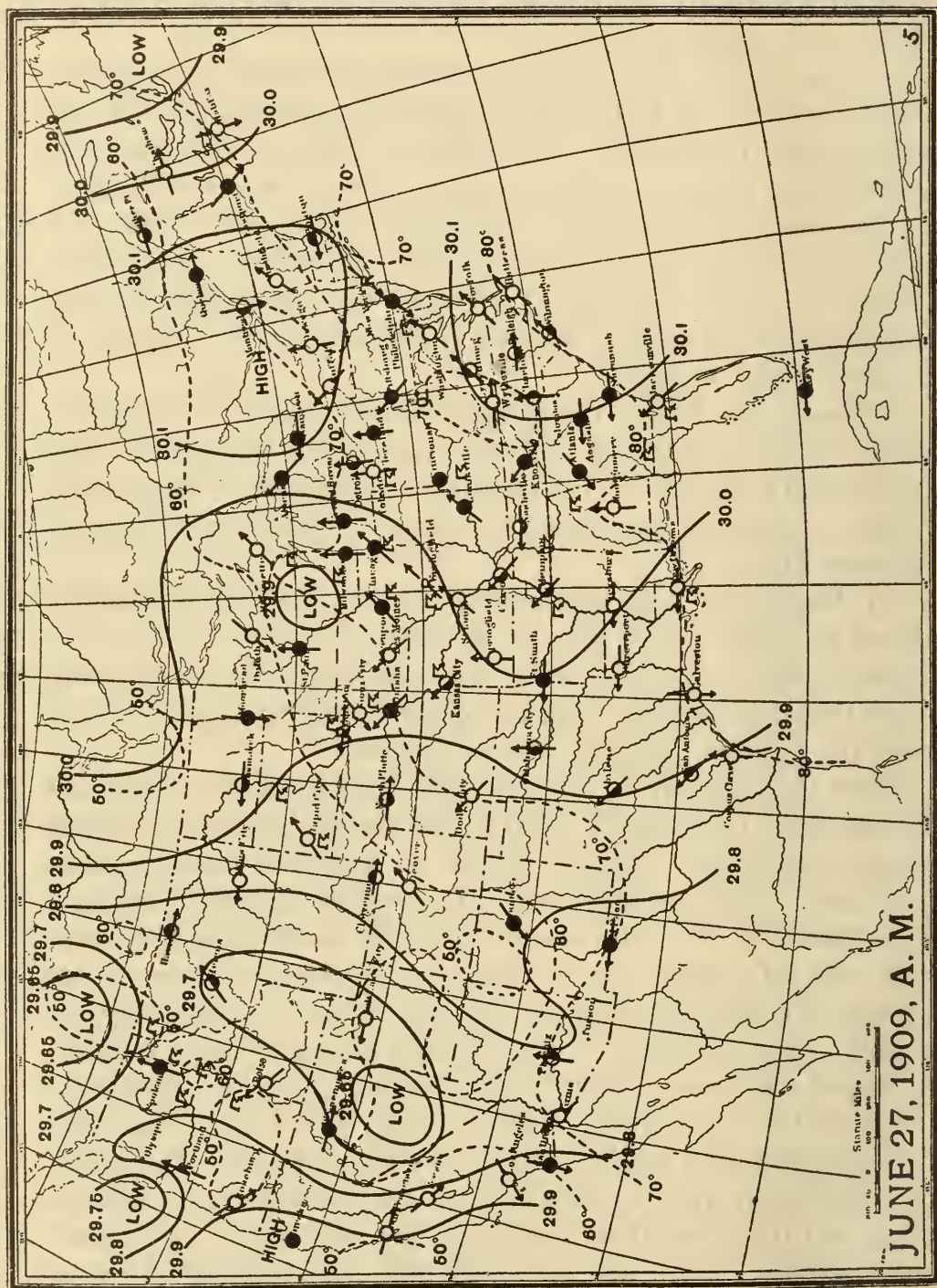
(a) Regions of high temperature and widely extended nearly uniform pressure. (See Figs. 5, 6, and 7.)

The conditions are still more favorable when the air is humid and the pressure, perhaps because of the humidity, slightly below normal or, at most, but little above normal.

When the pressure is approximately uniform the winds are light and every opportunity is given for the surface air to become strongly heated and thereby finally to establish thunderstorm convections. Such storms, always favored by mountain regions, and particularly by steep mountain peaks and strongly heated valleys, are, of course, most frequent on summer afternoons and are especially liable to occur at the end of two or three days of unusually warm weather. They develop here and there sporadically, hence the name "*local*" thunderstorm; last, as a rule, only an hour or two, and travel neither rapidly nor far. Those that form over mountain peaks often do not travel at all. The necessary initial convection is essentially, if not wholly, due to surface heating and therefore they frequently are referred to as "*heat*" thunderstorms. They are well-nigh the only type of thunderstorm in the tropics, and, perhaps, the most common type in the warmer portions of the temperate zones.

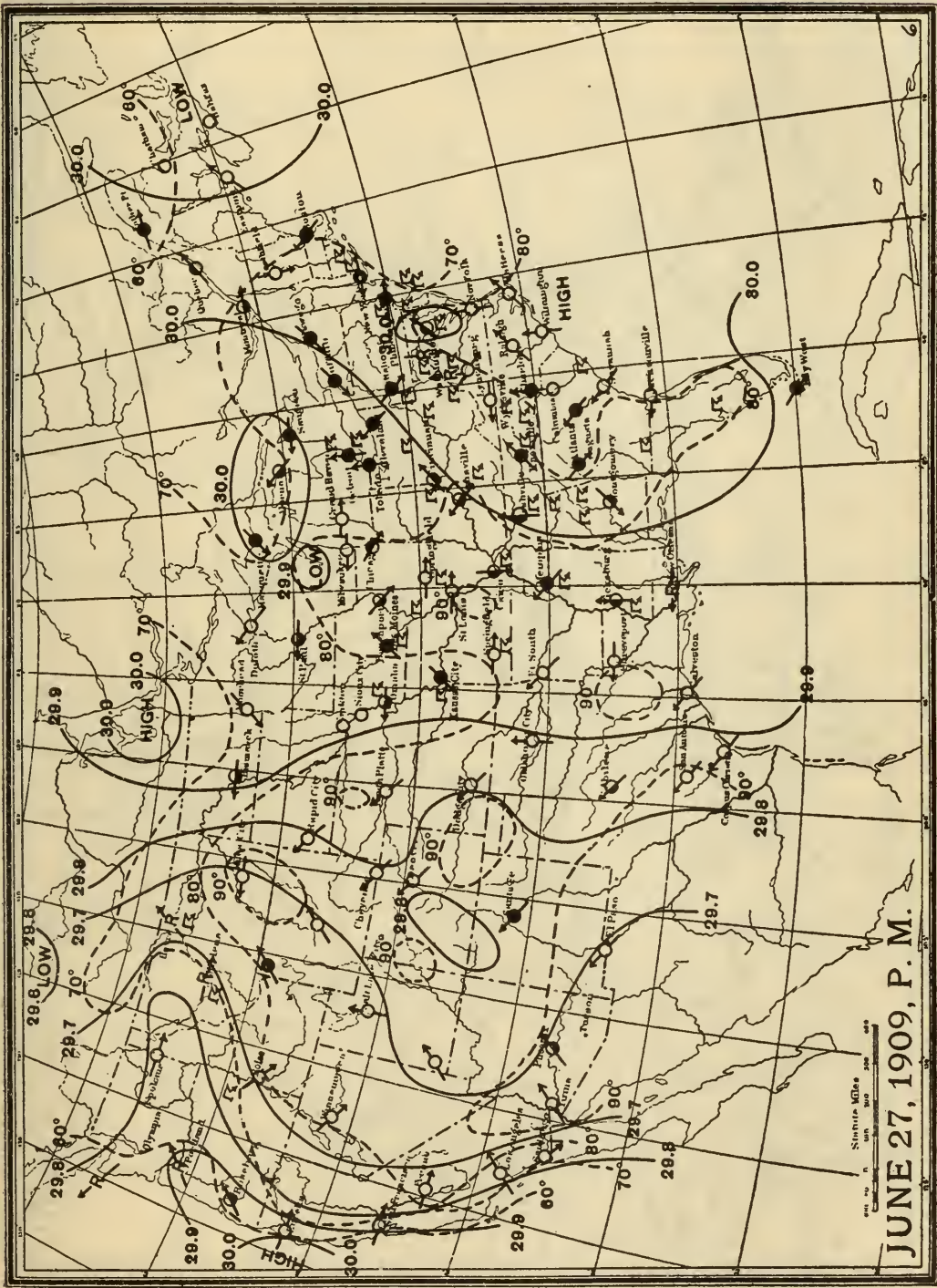
(b) The southeast quadrant (Southern Hemisphere, north-

FIG. 5.



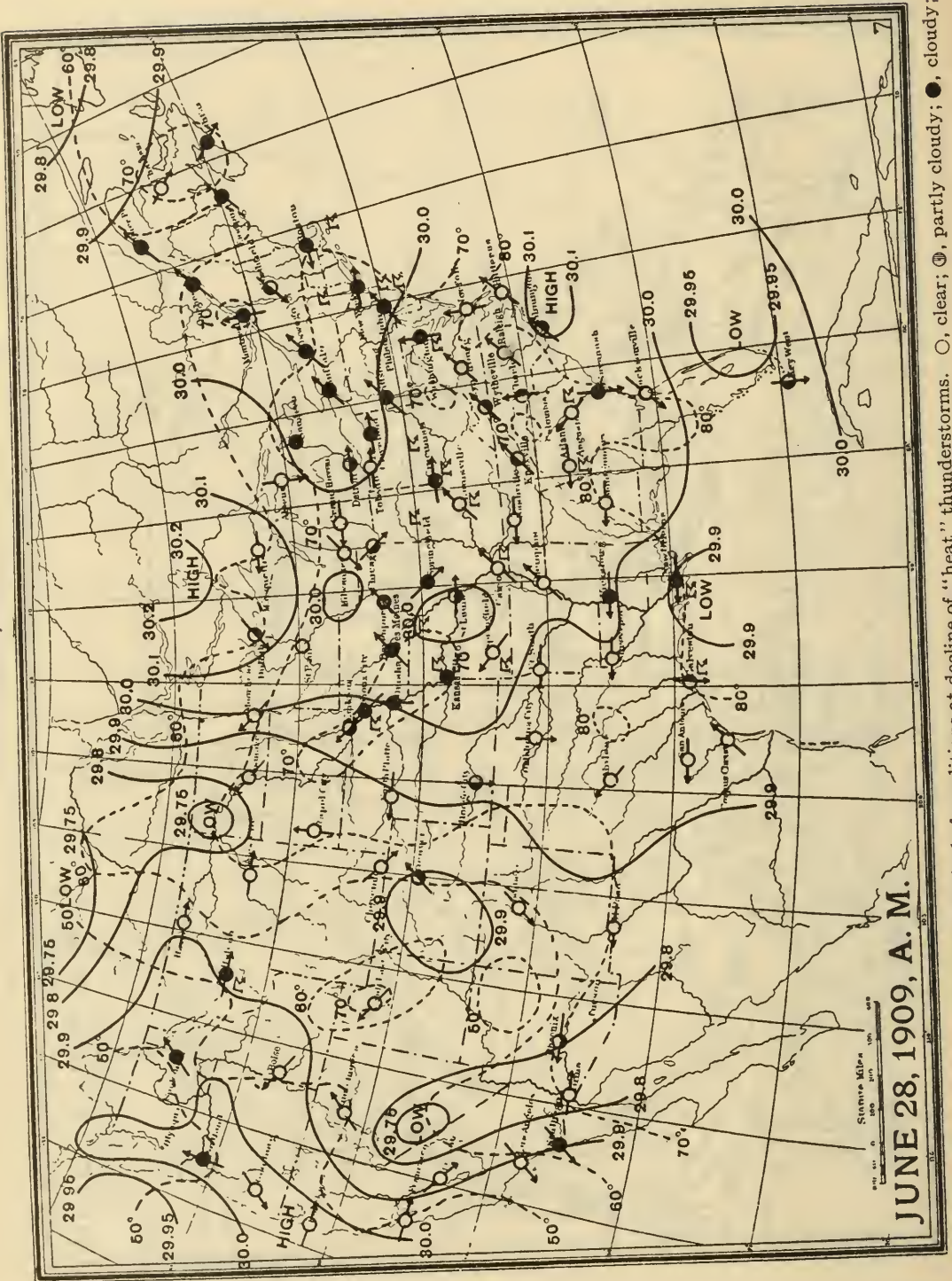
Weather map, 8 A.M., June 27, 1909, typical conditions at beginning of "heat" thunderstorms. O, clear; ●, partly cloudy; ⊗, cloudy; R, rain; ⚡, thunderstorm.

FIG. 6.



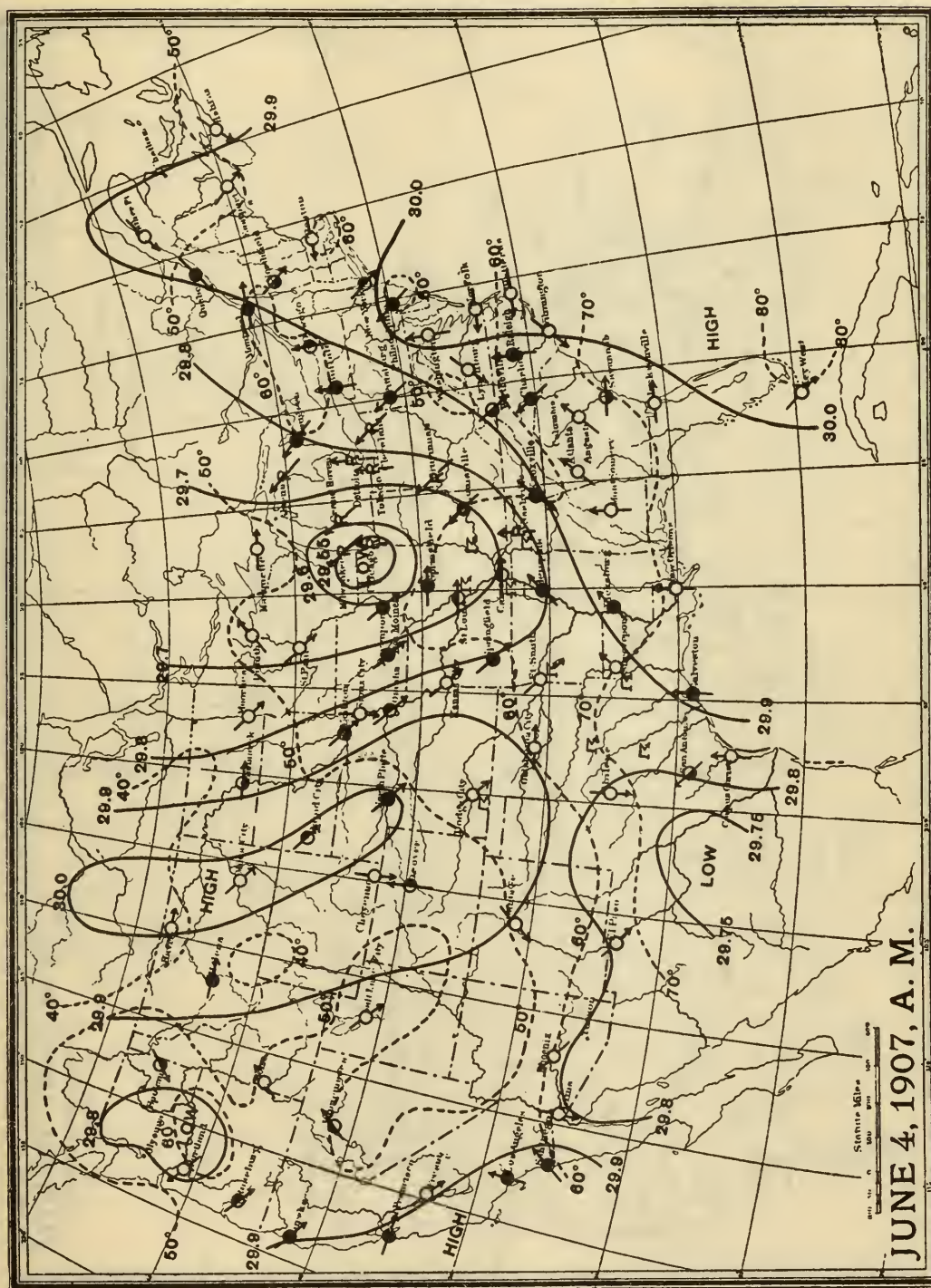
Weather map, 8 P.M., June 27, 1909, typical of "heat" thunderstorms. O, clear; \odot , partly cloudy; \bullet , rain; R, rain; R_c, thunderstorm.

FIG. 7.



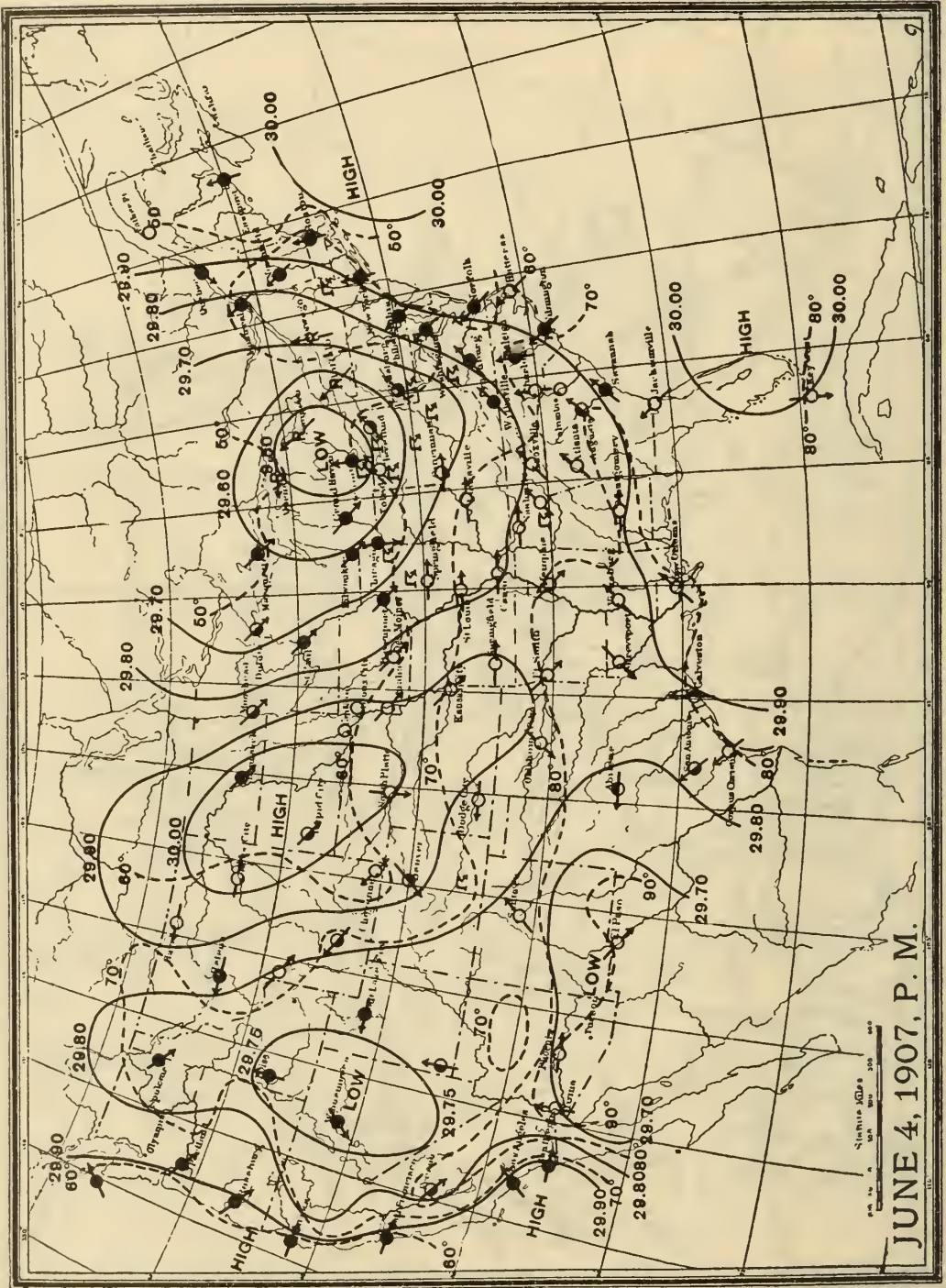
Weather map, 8 A.M., June 28, 1909, typical of conditions at decline of "heat" thunderstorms. O, clear; ◐, partly cloudy; ●, cloudy; R, rain; R_{th}, thunderstorm.

FIG. 8.



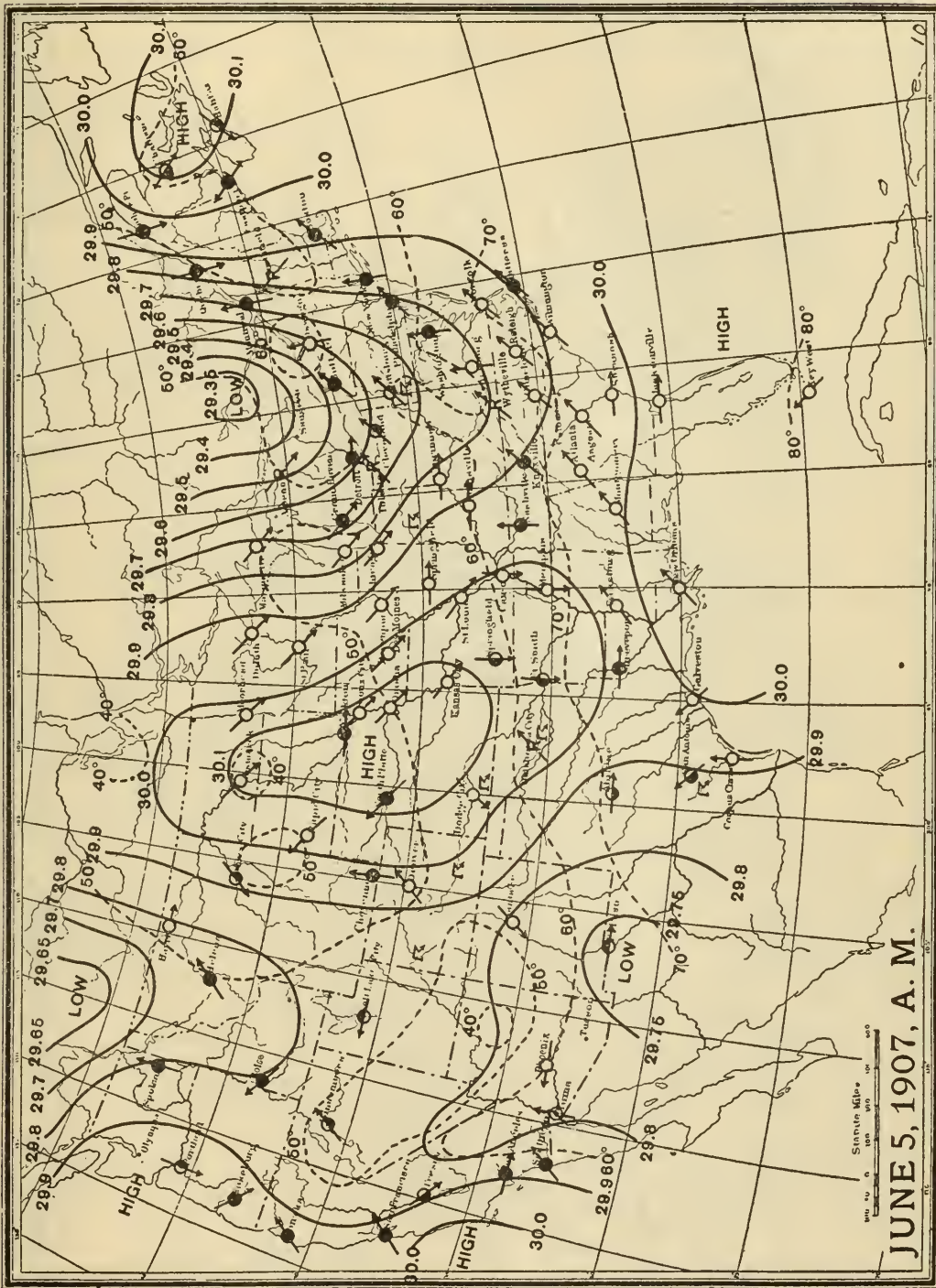
Weather map, 8 A.M., June 4, 1907, typical of conditions at beginning of "cyclonic" thunderstorms. O, clear; ⦿, partly cloudy; ●, cloudy; R, rain; R_s, thunderstorm.

FIG. 9.



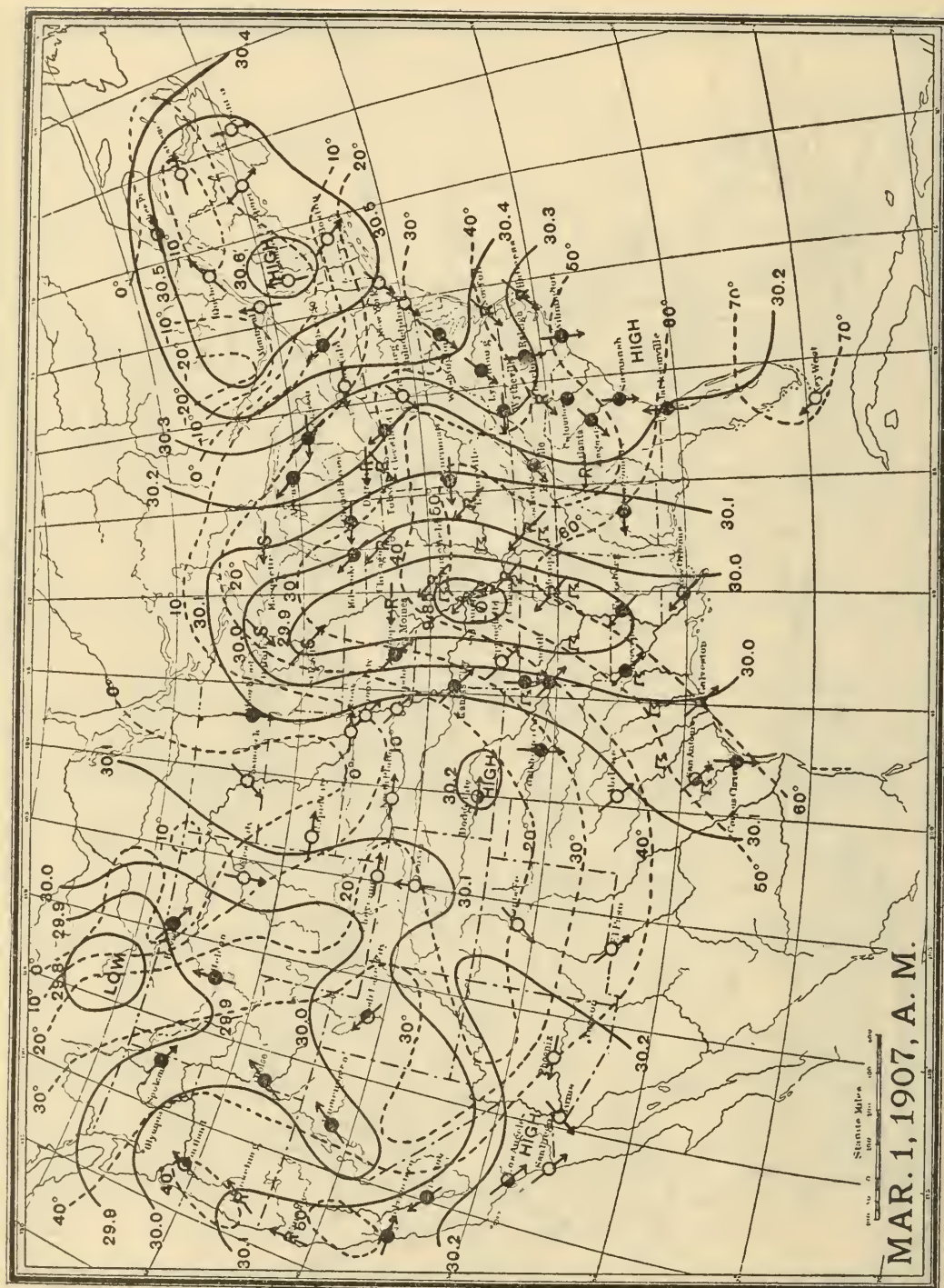
Weather map, 8 P.M., June 4, 1907, typical of "cyclonic" thunderstorms. O, clear; ◐, partly cloudy; ●, cloudy; R, rain; R_s, thunderstorm.

FIG. 10.



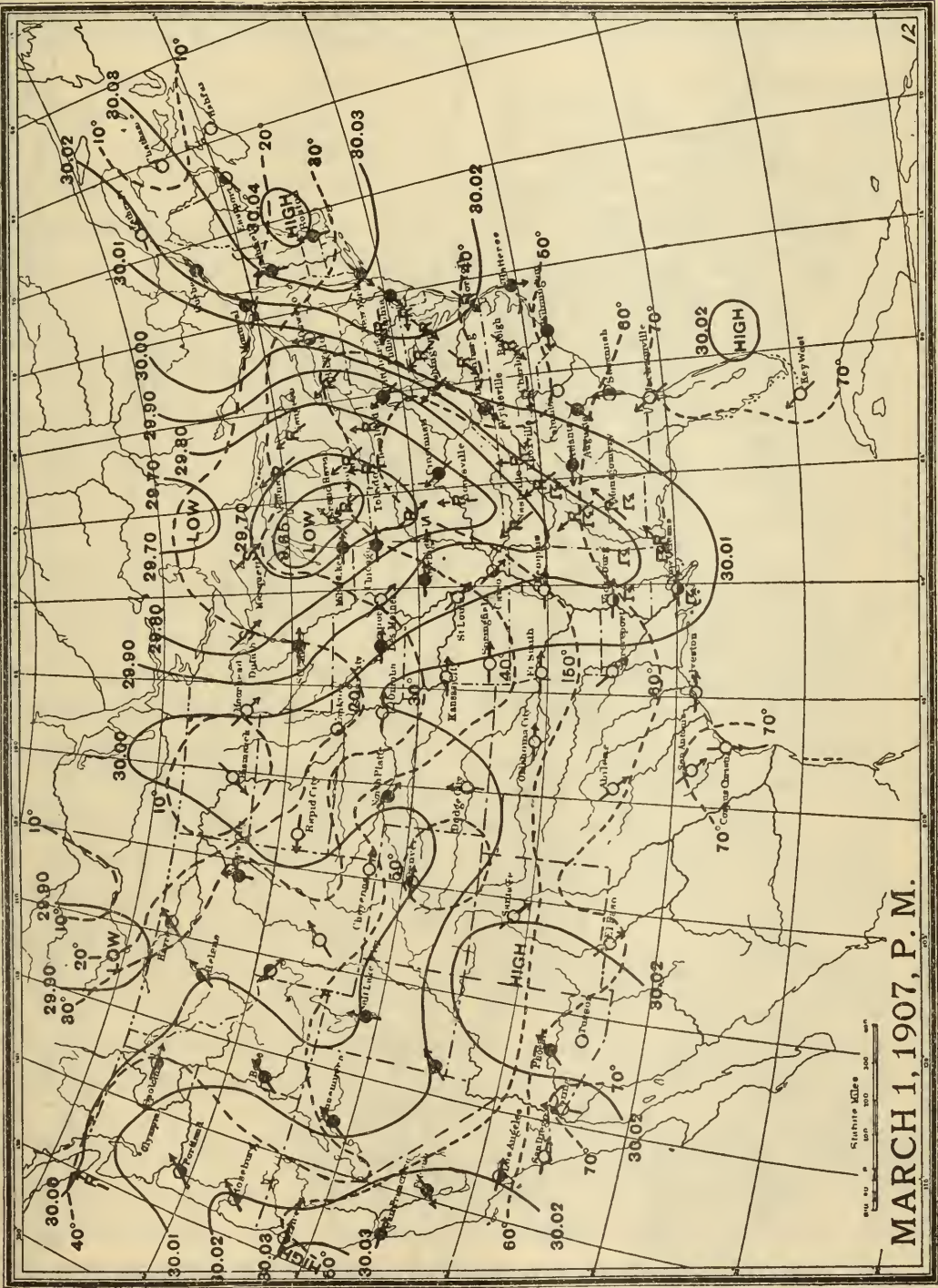
Weather map, 8 A.M., June 5, 1907, typical of conditions at decline of "cyclonic" thunderstorms. O, clear; \odot , partly cloudy; \bullet , cloudy; R, rain; R_{\downarrow} , thunderstorm.

FIG. II.

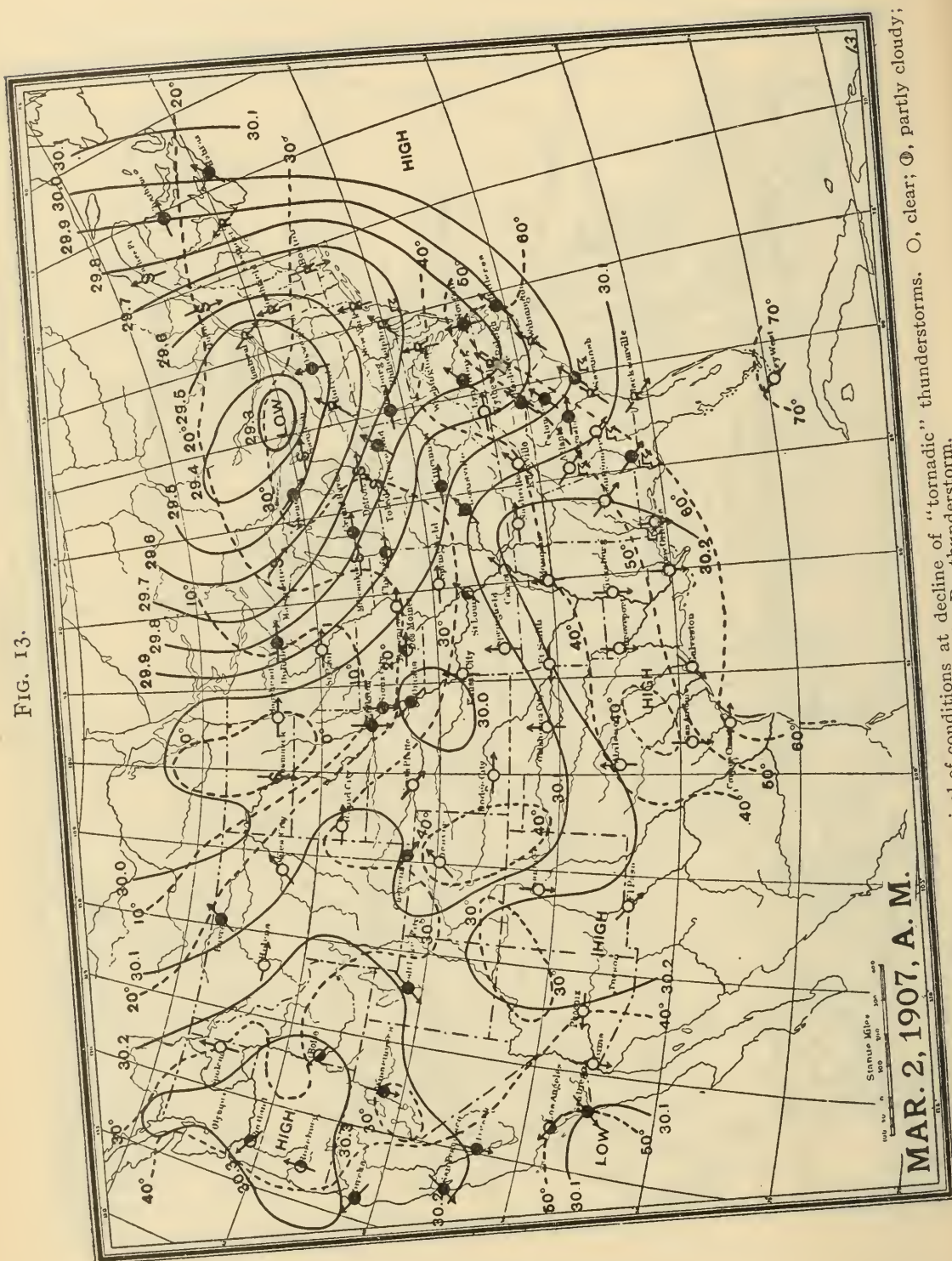


Weather map, 8 A.M., March 1, 1907, typical of conditions at beginning of "tornadic" thunderstorms. O, clear; ⊙, partly cloudy; ●, cloudy; R, rain; R+, thunderstorm.

FIG. 12.



Weather map, 8 P.M., March 1, 1907, typical of "tornadoic" thunderstorms. O, clear; ⊙, partly cloudy; ●, cloudy; R, rain; R₁, thunderstorm.



east), or, less frequently, the southwest (Southern Hemisphere, northwest), of a regularly formed low, or typical cyclonic storm. (See Figs. 8, 9, and 10.)

In this case the temperature gradient essential to a rapid vertical convection is not produced chiefly by local surface heating, as it is during the genesis of "heat" thunderstorms, but, in great measure, results from the more or less crossed directions of the under and over currents of air. The surface air of the quadrant in question normally flows from lower and warmer latitudes, while with increasing altitude the winds come more and more nearly from the west, or even northwest. This crossing of the air currents, then, the lower from warmer sections and the upper from regions not so much warmer—possibly even colder—progressively increases the vertical temperature gradient, or rate of temperature decrease with increase of altitude, and therefore may frequently be, and doubtless often finally is, the determining cause of a rapid vertical convection and the formation of a thunderstorm.

This particular type of thunderstorm, commonly known as the "*cyclonic*" thunderstorm, is almost wholly confined to the temperate and higher zones, for the simple reason that the well-defined cyclone, essential to its creation, seldom occurs in tropical or equatorial regions.

(c) The barometric valley beneath the branches of a distorted or V-shaped cyclonic isobar. (See Figs. 11, 12, and 13.)

This region is also favorable to the formation of secondary lows, which, though often of small area, sometimes are intense even unto tornadic violence.

Just how specific examples of this type of pressure distribution originated may not always be clear, but however established, each necessarily leads to opposing surface winds and also to more or less oppositely directed upper currents along adjacent paths; and each wind system, the lower and the upper, tends to produce an independent effect. Thus the opposing or conflicting surface winds cause such an irregular mixing of the air and such over and underrunning of currents as is likely to establish, here and there, a convection or thunderstorm gradient. Hence the frequency of thunderstorms along the valleys of low-pressure basins. On the other hand, the oppositely directed adjacent, not conflicting, upper currents by catching masses of air, especially rising

masses, between them tend mechanically to produce, in the middle atmosphere, violent vortices of limited extent. The more violent of these vertical atmospheric whirls, usually accompanied by thunder and rain and often extending down to the surface of the earth, where they become destructive, are known as tornadoes. Hence thunderstorms generated in the barometric region under discussion, the region in which tornadoes most frequently originate and develop, might properly be called "*tornadic*" thunderstorms.

Atmospheric conflicts and turmoil, of the nature just described, obviously may occur at any place along the protrusion, or valley, of the low-pressure basin, and therefore often do occur, even simultaneously, here and there, along its entire length, and together from the well-known "line squall." Besides, as the whole cyclonic condition moves forward in general from west to east, maintaining, in a measure, for many hours its identity of form and nature, it follows that its valley of low pressure, and therefore its line of thunderstorms, must also travel with it in the same general direction and with approximately the same velocity.

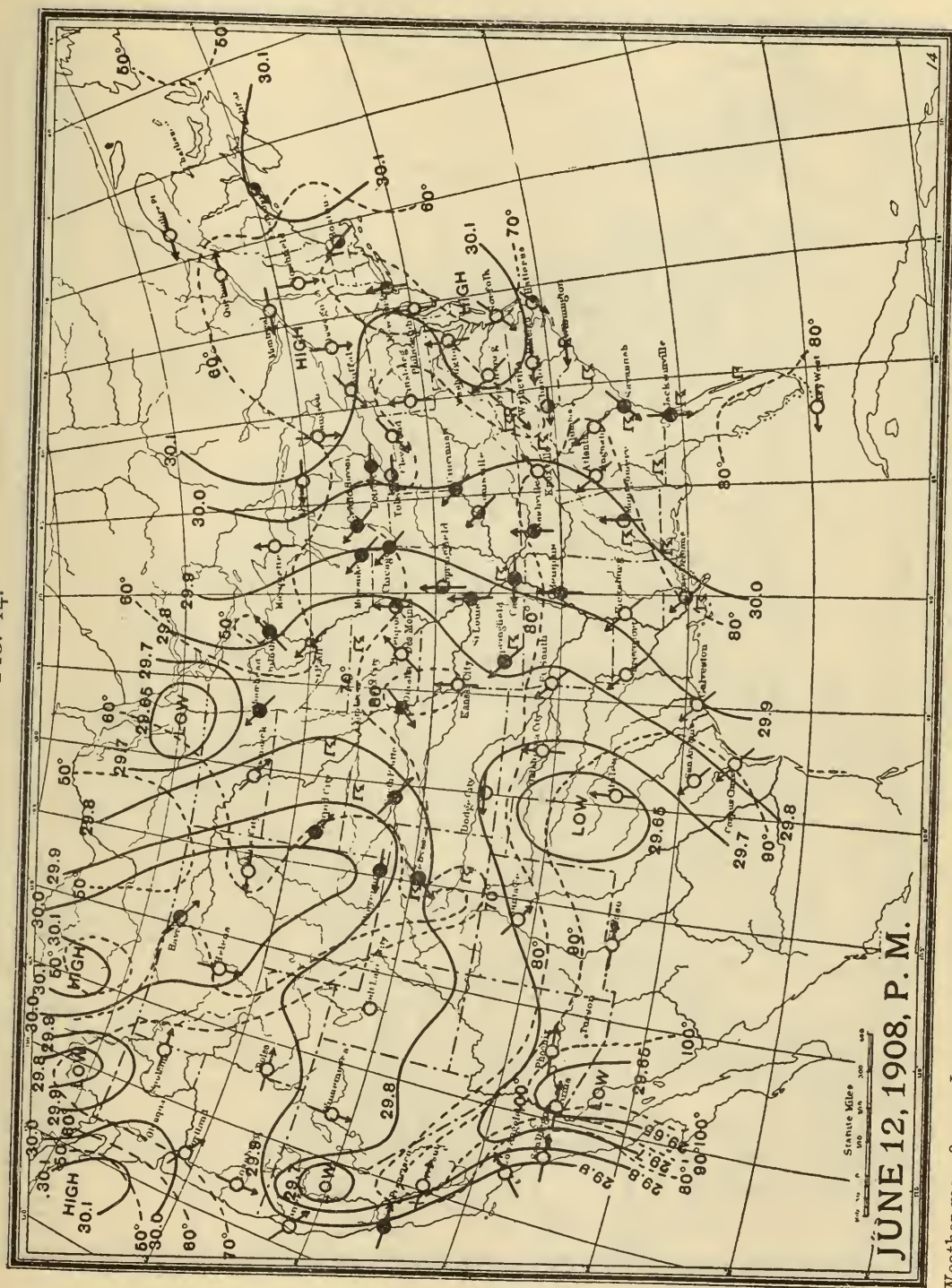
A line or row of thunderstorms—a "line squall"—as observations show, always moves across its own axis, not necessarily at right angles, but nevertheless across and not parallel to it, nor even approximately so. The chief reason for this is not the axial direction of the low-pressure valley which, indeed, though usually running south, may have any orientation from the parent basin, but rather the fact that the valley itself, together with its accompanying thunderstorm conditions, travels across and not along its own direction.

In this connection it is also worth noting that the temperature distribution in the wake of a thunderstorm renders the occurrence of an immediate successor improbable, as will be explained later. Hence, while a considerable number of thunderstorms may and often do travel abreast, they can never follow each other closely in file.

(*d*) The region covered by a low-pressure trough between adjacent high-pressure areas. (Figs. 14, 15, and 16.)

Along the adjacent borders of two neighboring anticyclones—that is, along the barometric trough between them—the surface winds from one side are more or less directly opposed to those from the other. Hence, because of the overrunning, as explained under (*c*), and the resulting temperature gradients, this also is a

FIG. 14.



Weather map, 8 p.m., June 12, 1908, typical of conditions at beginning of "trough" thunderstorms. O, clear; ●, partly cloudy, ●, cloudy; R, rain; R₁, thunderstorm.

FIG. 15.



FIG. 16.



Weather map, 8 p.m., June 13, 1908, typical conditions at decline of "trough" thunderstorms. O, clear; \odot , partly cloudy; \bullet , cloudy; R, rain; R \searrow , thunderstorm.

region of frequent thunderstorms. Here, too, a number of more or less independent storms may exist simultaneously along the same line, and advance abreast for great distances across the country.

There does not appear to be any independent or distinctive name for the thunderstorm generated under this type of pressure distribution. Perhaps it might, with some justification, be called the "*anticyclonic*" thunderstorm, or even the "*trough*" storm.

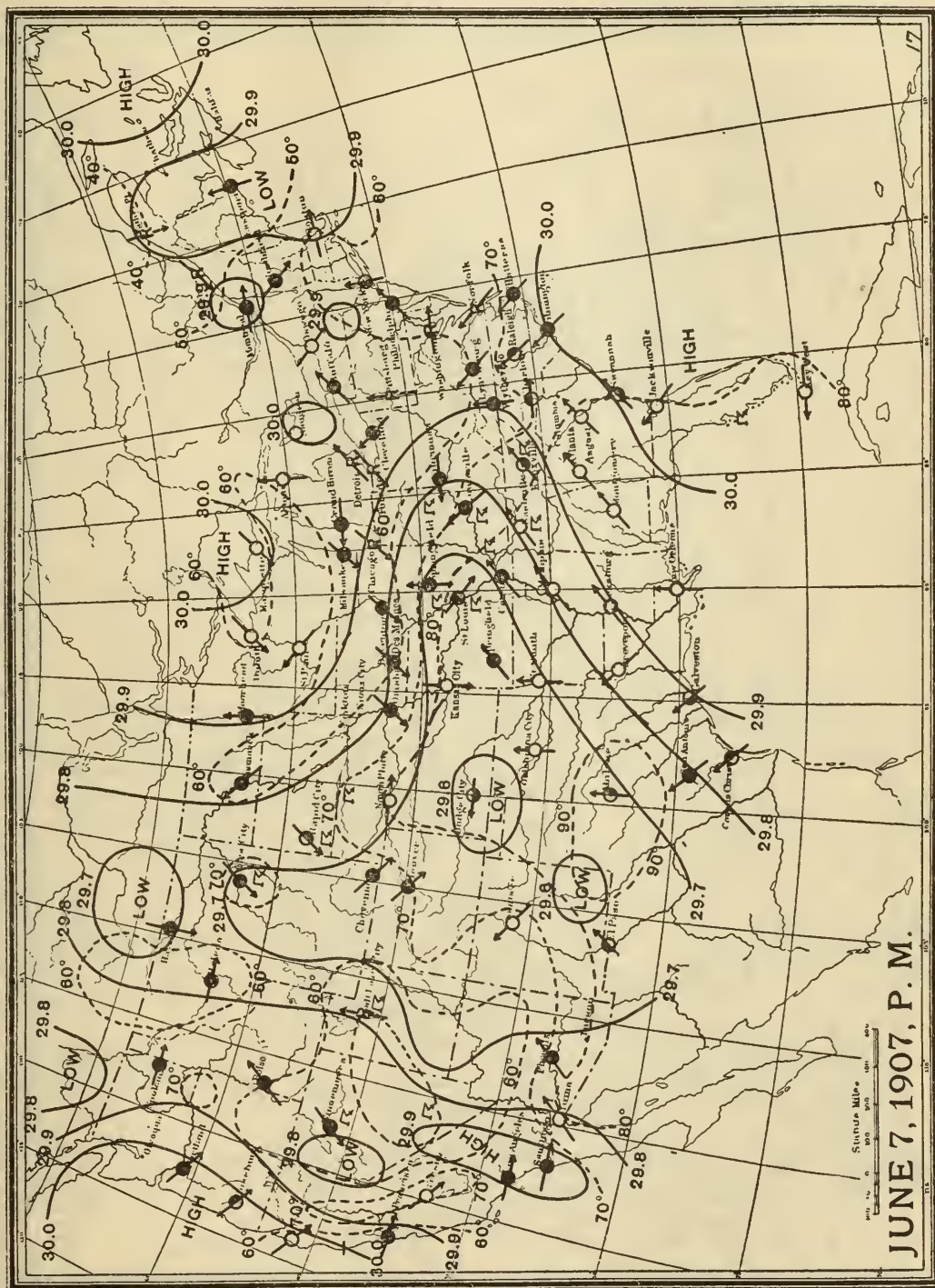
(e) The boundary between warm and cold waves. (See Figs. 17, 18, and 19.)

Along such a boundary the direction of flow of the warm humid layers of air is more or less opposite, as shown on the maps, to that of the colder ones. Therefore it must frequently happen that at irregular intervals along such a boundary the upper air, coming from the cold area, overruns a section of surface air belonging to the warm region; but, of course, only where the upper air is till potentially warmer than the lower—if potentially colder it would underrun. Now, wherever this overrunning on the part of the cold air does occur the vertical temperature gradient obviously is abruptly and greatly increased, and wherever, in the course of its further movement, the new gradient exceeds the adiabatic rate of temperature change, as analogous to case (b), it often must, under the given conditions, vertical convection with rain, thunder, and lightning is apt to occur. Hence, as stated, the boundary between warm and cold waves is another place favorable to the thunderstorm, which, under these conditions, possibly might be called the "*border*" storm.

These five distinct types of weather conditions, together with their innumerable variations and combinations, probably include all that are distinctly favorable to the production of thunderstorms. Each tends to establish an adiabatic or even superadiabatic temperature gradient up to the cloud level—the one thing essential to the production of a strong vertical convection, the progenitor, as we have seen, of the thunderstorm.

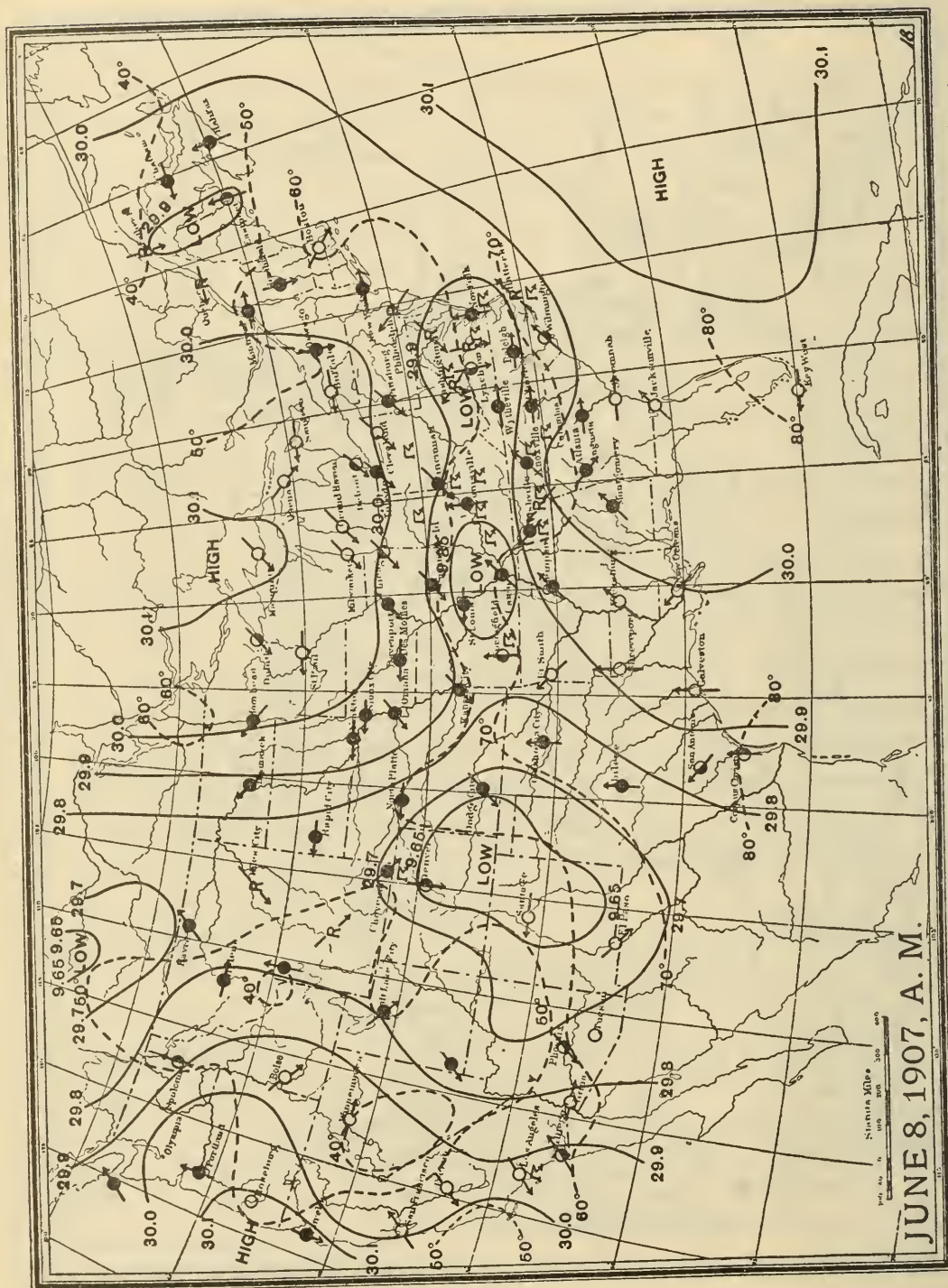
Thunderstorm Winds.—Shortly, say 20 minutes or so, before the rain of a thunderstorm reaches a given locality the wind at that place, which generally is light and from the south or southwest across the path of the storm, begins to die down to an approximate calm and to change its direction. When this change is complete, it blows for a few minutes, rather gently, directly

FIG. 17.



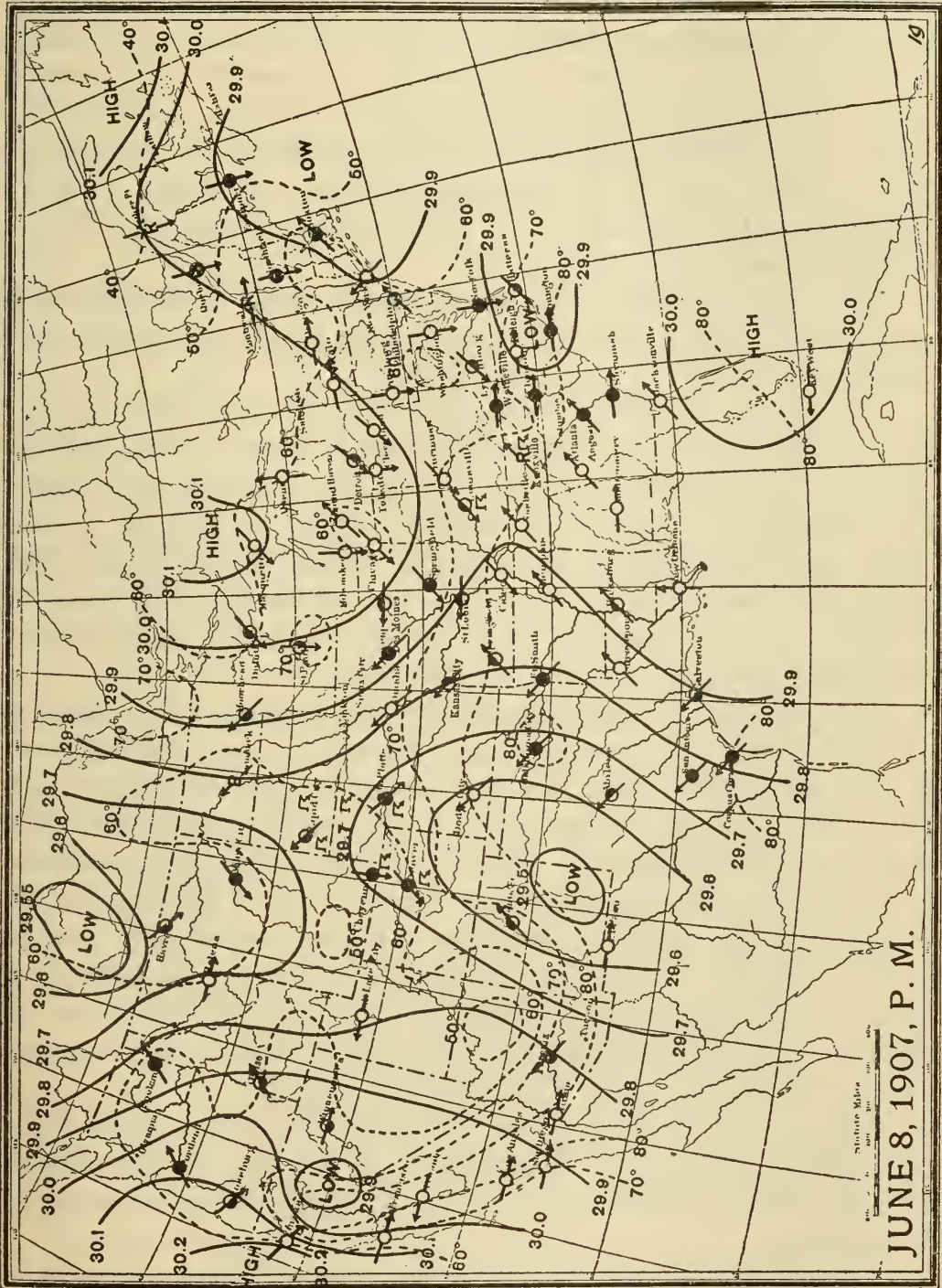
Weather map, 8 P.M., June 7, 1907, typical of conditions at beginning of "border" thunderstorms. O, clear; R, partly cloudy; ●, cloudy; R, rain; R, thunderstorm.

FIG. 18.



Weather map, 8 A.M., June 8, 1907, typical of "border" thunderstorms. O, clear; ●, partly cloudy; R, rain; R₊, thunderstorm.

FIG. 19.



Weather map, 8 P.M., June 8, 1907, typical of conditions at decline of "border" thunderstorms. O, clear; ⊙, partly cloudy; ⊗, cloudy; R, rain; R₊, thunderstorm.

toward the nearest portion of the storm front, and finally, as the rain is almost at hand, again, but this time abruptly and in rather violent gusts, away from the storm and in the same direction that it is travelling, a direction that usually differs appreciably from that of the original surface wind. Generally this violent gusty wind lasts through only the earlier portion of the storm, and then is gradually but rather quickly succeeded by a comparatively gentle wind that, though following the storm at first, frequently, after an hour or so, blows in the same general direction as the original surface wind.

The cause of the thunderstorm winds needs to be carefully considered if one would understand at all clearly the mechanism of the storm itself.

As already explained, this type of storm owes its origin to that vertical convection which results from a more or less superadiabatic temperature gradient. It is this gradient, no matter how established, whether by simple surface heating or by the over- and underrunning of unequally heated layers of air, that permits, or rather forces, the production of the cumulus cloud in which and by the motions of which the electricity that characterizes the storm in question is generated.

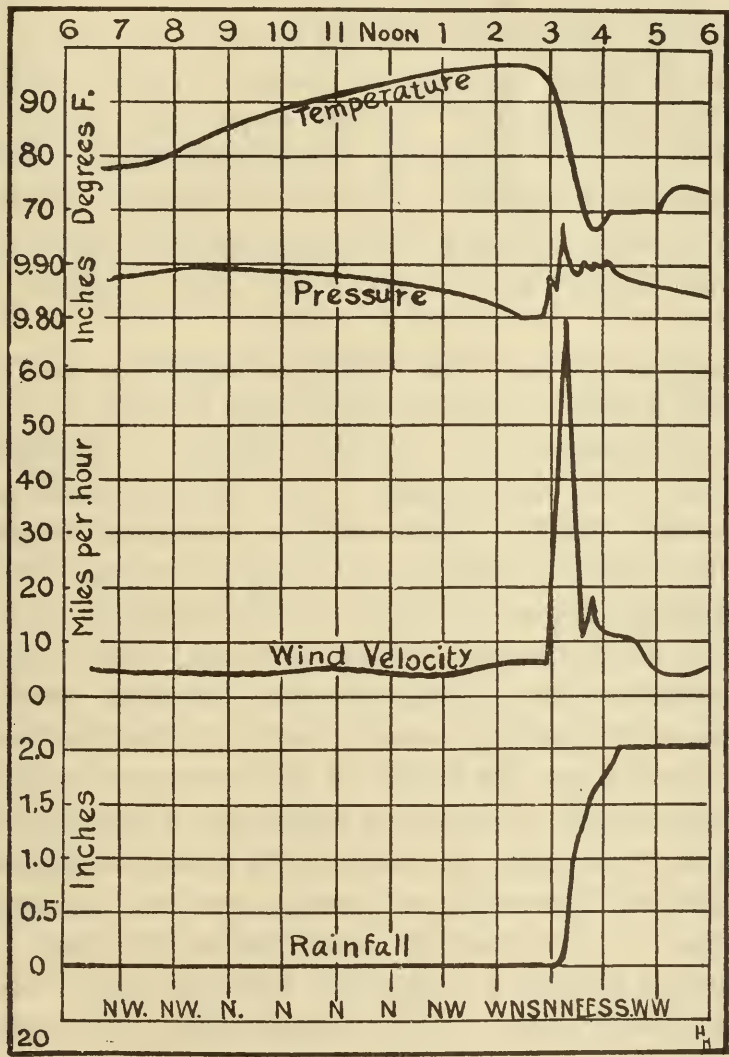
Nevertheless, as everyone knows, the passage of a cumulus cloud overhead, however large, so long as no rain is falling from it, does not greatly affect the direction and magnitude of the surface wind—does not bring on any of the familiar gusts and other thunderstorm phenomena. Hence we must infer that somehow or other the rain is an important factor both in starting and in maintaining the winds in question, for they do not exist before the rain begins nor continue after it has ceased. On the other hand, it cannot be assumed that the rain is the whole cause of these winds, for they do not accompany other and ordinary showers, however heavy the downpour may be.

The actual course of events, illustrated by Fig. 20, taken from the records obtained at Washington, D. C., during the passage of the notable thunder squall of July 30, 1913, seems to be about as follows:

First.—An approximately adiabatic temperature gradient is established over a wide area, roughly up to the base level of the cumulus clouds. But while the uprising branches of the existing convection currents, due to superadiabatic gradients, may

be localized and here and there rather rapid, the return or down-flow, though really the cause of the updraft, is widespread and correspondingly gentle. The condition essential to a local and rapid downflow—that is, a local decided cooling at a high altitude

FIG. 20.



Course of meteorological elements on a thunderstorm day, at Washington, D. C. (July 30, 1913).

—does not exist, and therefore the counterpart to the upward currents is nowhere conspicuous.

Second.—After a time, as a result of strong convection in a cumulus cloud, rain is formed at a considerable altitude where, of course, the air is quite cold, in fact so cold that hail is often produced. Now this cold rain, or rain and hail, as it falls, and as long as it falls, chills the air from the level of its formation all

the way to the earth, partly as a result of its initial low temperature and partly because of the evaporation that takes place during its fall. Hence this continuously chilled column of air because, somewhat, of the frictional drag of the rain, but mainly because of the increase, due to this chilling, of its own density, immediately and necessarily becomes a concentrated and vigorous, or swiftly flowing, return branch of the vertical circulation. In fact, it (or gravity acting through it) becomes the sustaining cause of the storm's circulation. At the same time, because of the downward blow and because of surface friction, as will be explained later, the barometric pressure is abruptly increased.

It will be worth while to consider some of these statements a little more closely, and to test them with possible numerical values.

Omitting, as we may, the effects of radiation, there seem to be but three possible ways by which the cooling of a thunderstorm may be obtained: (*a*) By the descent of originally potentially cold air. (*b*) By chilling the air with the cold rain. (*c*) By evaporation. Each of these will be considered separately.

(*a*) Obviously no portion of the upper air could maintain its position if potentially even slightly colder than that near the surface. If at all potentially colder it would fall until it itself became the surface air, as indeed is the case in all vertical circulation. Hence the great decrease in temperature that comes with a thunderstorm is not the result of the descent of a layer of air originally potentially cold for, as explained, an upper layer sufficiently cold to give, after its descent, the actual cooling could not exist. Again, any descending air must come from either below the under surface of the cloud or from above this level. If from below, it must, because of adiabatic heating, reach the earth at substantially the original surface temperature. If from above it would, as is obvious from Fig. 1, reach the earth even warmer than the original surface temperature. Hence, looked at in any way, case (*a*) obviously is inadmissible.

(*b*) Let the under surface of the thunderstorm cloud be 1500 metres above the earth, and the column of air cooled by the cold rain and its evaporation 2000 metres high. Let the surface temperature be 30° C., and the temperature gradient before the storm begins adiabatic up to the under-cloud level, and let there be a 2-centimetre rainfall.

Now, at the temperature assumed, a column of air 2000 metres high whose cross-section is 1 square centimetre weighs, roughly, 210 grammes, and its heat capacity, therefore, is approximately that of 50 grammes of water. At the top of this column the temperature can be, at most, only about 20° C. lower than at the bottom, and if the rain leaves the top at this temperature but reaches the earth 7° C. colder than the surface air before the storm (temperatures that seem at least to be of the correct order) it will have been warmed 13° C. during its fall and the air column cooled on the average about 0.5° C. But, as a matter of fact, the air usually is cooled by from 5° C. to 10° C. Hence, while the temperature of the air necessarily is reduced to some extent by mere heat conduction to the cold rain much the greater portion of the cooling clearly must have some other origin. Further, since (*a*) is inadmissible and (*b*) only a minor contributing factor, it follows that by exclusion only evaporation is left to account for much the greater portion of the cooling. Let us see, then, if evaporation really is adequate to meet these demands.

(*c*) It is a common thing in semiarid regions to see a heavy shower, even a thundershower, leave the base of a cloud and yet fail utterly, because of evaporation, to reach the surface of the earth. Hence it appears quite certain that in the average thunderstorm a considerable portion of the rain that leaves the cloud is evaporated before it reaches the ground, and therefore that the temperature decrease of the atmosphere is largely owing to this fact. But if so, why, then, one might properly ask, does not an equally great temperature drop accompany all heavy rains?

The answer is obvious, because, as a rule, the temperature is higher and the relative humidity lower during a thunderstorm than at the time of any other ordinary rain. The chief, perhaps the sole, reason for this difference in relative humidity is the difference in the two cases between the movements of the air. In the thunderstorm the descending air, which can be no more than saturated at top, dynamically warms so rapidly and is so continuously renewed that evaporation into it cannot keep pace with its vapor capacity. During other rains, however, where there is no atmospheric descent, and therefore no dynamical heating, approximate saturation must soon obtain; hence but little further evaporation and, of course, but little cooling.

We will now return to the numerical values and compute a probable magnitude of cooling due to evaporation.

As before, let a 2-centimetre rain leave the cloud, but let one-fourth of the rain that started, or half a centimetre, be evaporated. This would consume 303 heat units from an air column 2000 metres high whose heat capacity is that of only 50 cubic centimetres of water. Hence, as a result of evaporation alone, the temperature of the air column would be lowered on the average by about 6° C. Evaporation, therefore, appears to be both necessary and sufficient to produce all or nearly all the cooling of a thunderstorm.

Since the molecular weight of water is 18, while the average molecular weight of air is approximately 29, it follows that the amount of evaporation above assumed would decrease the density of the atmosphere by, roughly, one part in a thousand. On the other hand, a decrease in temperature of 6° C., that would be produced by the evaporation assumed, would increase the density by about one part in fifty. Hence the resultant of these two opposing effects is substantially that of the second alone; that is, a distinct increase in the density.

Doubtless, as already stated, the evaporation of thunderstorm rain, and therefore the drop in temperature and the consequent gain in density, all increase with decrease of elevation. In some measure, however, this effect is counteracted by the increasing rate of dynamical heating in the lower layers resulting from the correspondingly increased rate of pressure gain to change in elevation.

But no matter how or to what extent the details may vary, it seems quite certain that the cold rain of a thunderstorm and its evaporation together must establish a local downrush of cold air—an observed important and characteristic phenomenon, really the immediate cause of the vigorous circulation, whose rational explanation has been attempted in the last few paragraphs.

As the column or sheet of cold air flows down it maintains in great measure its original velocity and, therefore, on reaching the earth rushes forward in the direction of the storm movement, underrunning and buoying up the adjacent warm air. And this condition—largely due, as explained, to condensation and evaporation—once established is necessarily self-perpetuating, so long as the general temperature gradient, humidity, and wind

direction are favorable. It must be remembered, however, that thunderstorm convection, rising air just in front and descending air with the rain, does not occur in a closed circuit, for the air that goes up does not return nor does the air that comes down immediately go up again; there simply is an interchange between the surface air in front of the storm and the upper air in its rear. The travel of the storm, by keeping up with the underrunning cold current, just as effectually maintains the temperature contrast essential to this open-circuit convection as does continuous heating on one side and cooling on the other maintain the temperature contrast essential to a closed circuit convection.

The movements of the warm air in front of the rain, the lull, the inflow, and the updraft resemble somewhat those of a horizontal cylinder resting on the earth where the air is quiet and rolling forward with the speed of the storm. Similarly, the cold air in its descent and forward rush, together with the updraft of warm air, also resembles a horizontal cylinder, but one sliding on the earth and turning in the opposite direction from that of the forward-rolling or all-warm cylinder. In neither case, however, is the analogy complete, for, as above explained, the air that goes up remains aloft while the cold air that comes down is kept by its greater density to the lower levels. The condition of flow persists, as do cataracts and crest clouds, but here, too, as in their case, the material involved is ever renewed.

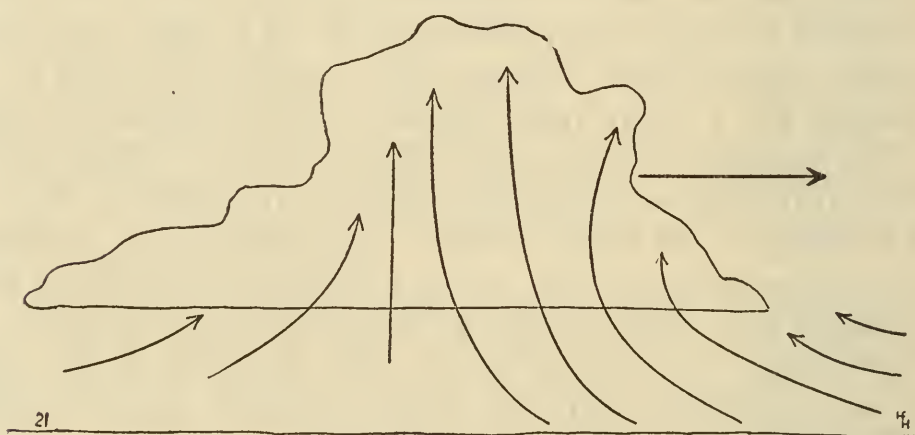
The Squall Cloud.—Between the uprising sheet of warm air and the adjacent descending sheet of cold air horizontal vortices are sure to be formed in which the two currents are more or less mixed. The lower of these vortices can only be *inferred* as a necessary consequence of the opposite directions of flow of the adjacent sheets of warm and cold air, for there is nothing to render them visible. Neither can any vortices that may exist within the cloud be seen. Near the front lower edge of the cumulo-nimbus system, however, and immediately in front of the sheet of rain, or rain and hail, the rising air has so nearly reached its dew point that the somewhat lower temperature, produced by the admixture of the descending cold air, is sufficient to produce in it a light fog-like condensation which, of course, renders any detached vortex at this position quite visible.

This squall cloud, in which the direction of motion on top is

against the storm, may be regarded as a third horizontal thunderstorm cylinder much smaller but more complete than either of the others.

Schematic Illustrations.—The above conceptions of the mechanism of a thunderstorm can, perhaps, be made a little clearer with the aid of illustrations. Fig. 21, a schematic picture of a thunderstorm in the making, gives the boundary of a large cumulus cloud from which rain has not yet begun to fall, and the stream lines of atmospheric flow into it. When the cloud is stationary and there is no surface wind the updraft obviously will be more or less symmetrical about a vertical through its centre,

FIG. 21.



Principal air movements in the development of a cumulus cloud.

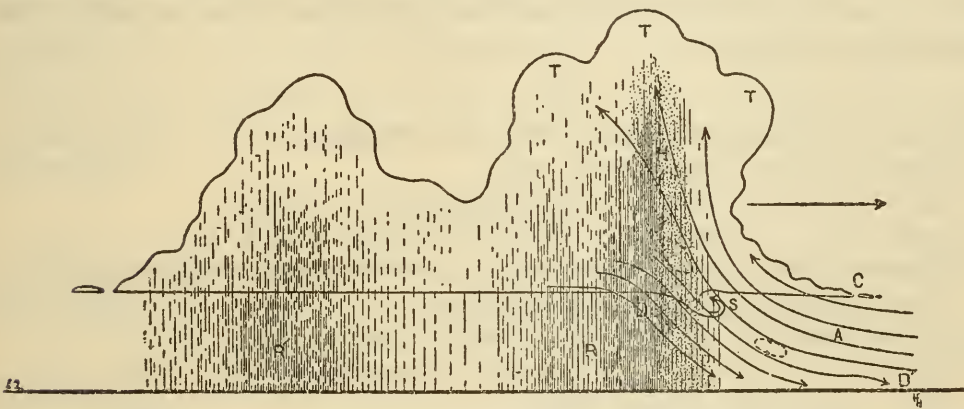
but when it has an appreciable velocity, as indicated in the figure, it is equally obvious that most, often nearly all, of the air entering the cloud will do so through its front under-surface. At this stage there will be no concentrated or local down current, only an imperceptible counter settling of the air round about, because, as previously explained, the air cataract requires local cooling to subpotential temperatures, and this in turn requires local rain.

Fig. 22 schematically represents a well-developed thunderstorm in progress. The falling rain, often mixed with hail, cools the air through which it falls, and as the temperature gradient was already closely adiabatic it follows that the actual temperatures will be subpotential from the surface of the earth to within the cloud, or throughout and a little beyond the non-saturated or evaporating levels. As soon, then, as this column or sheet of

air is sufficiently cooled it flows down and forward and all the atmospheric movements peculiar to the thunderstorm are established substantially as shown.

Referring to the figure: The warm ascending air is in the region *A*; the cold descending air at *D*; the dust cloud (in dry weather) at *D'*; the squall cloud at *S*; the storm collar at *C*; the thunder heads at *T*; the hail at *H*; the primary rain, due to initial convection, at *R*; and the secondary at *R'*. This latter phenomenon, the secondary rain, is a thing of frequent occurrence and often is due, as indicated in the figure, to the coalescence

FIG. 22.



Ideal cross-section of a typical thunderstorm. *A*, ascending air; *D*, descending air; *C*, storm collar (*Sturmkragen*); *S*, roll scud; *D'*, wind gust; *H*, hail; *T*, thunderheads; *R*, primary rain; *R'*, secondary rain.

and quiet settling of drops from an abandoned portion of the cumulus in which and below which winds and convection are no longer active.

Mammato-cumuli rarely, false cirri frequently, and cap-clouds occasionally, accompany thunderstorms, but as they are not essential to it they therefore are omitted from the above schematic illustration.

Thunderstorm Pressures.—Before the onset of a thunderstorm there usually if not always is a distinct fall in the barometer. At times this fall is extended over several hours, but whether the period be long or short the rate of fall usually is greatest at the near approach of the storm. Just as the storm breaks, however, the pressure rises very rapidly, almost abruptly, usually from 1 to 2 millimetres, fluctuates irregularly, and finally as the

storm passes again becomes rather steady but at a somewhat higher pressure than prevailed before the storm began.

The cause of these pressure changes is, doubtless, rather complex. The decrease in the absolute humidity and the decrease in temperature both tend to increase the atmospheric pressure, and, presumably, each contributes its share. Both these effects, however, are comparatively permanent, and while they may be mainly responsible for the increase of pressure that persists after the storm has gone by, they probably are not the chief factors in the production of the initial and quickly produced pressure maximum. Here at least two factors, one obvious, the other inconspicuous, are involved. These are: (a) The rapid downrush of air, and (b) the interference to horizontal flow caused by the vertical circulation.

¹ Memoirs, Indian met'l. dept., Simla, 1910, 20, pt. 8.

² *Physikal. Ztschr.*, Leipzig, 1906, 7, 98.

³ Sitzber, K. preuss. Akad. d. Wiss., Berlin, 1892, 8, 279-309.

⁴ Braak, *Beitr. z. Physik d. fr. Atmosph.*, Leipzig, 1914, 6, 141.

⁵ Hellmann, "Die Niederschläge in den Norddeutschen Stromgebieten," Berlin, 1906, vol. 1, pp. 336-337, and elsewhere.

⁶ *Meteorologische Zeitschrift*, Braunschweig, 1908, 25, Jhrg., 108.

⁷ Steffens, Otto, *Ztschr. f. d. gesamte Versicherungswiss.*, Berlin, 1904, 4, pt. 4. (Also Diss.-Berlin, 1904.)

⁸ Humphreys, W. J., Bull., Mt. Weather Obs'y, Washington, 1913, 6, 1.

(To be concluded in December.)

Belgian Blast Furnaces. ANON. (*Eng.*, xcvi, No. 2529, 859.)
 —The number of furnaces in blast in Belgium and in the Luxembourg at the beginning of June was 49, as compared with 52 at the beginning of June, 1913. The number of furnaces out of blast at the commencement of June, 1914, was 11, as compared with three on the corresponding period of 1913. The 49 furnaces in blast at the beginning of June were distributed as follows: Hainaut and Brabant, 24; Liège group, 18; Luxembourg, 7. The production of pig iron in Belgium and the Luxembourg in May was 215,020 tons, as compared with 224,550 tons in May, 1913, while in the five months ended May 31, this year, the aggregate output was 1,029,050 tons, as compared with 1,007,760 tons in the corresponding period of 1913. The total of 1,029,050 tons representing this year's aggregate output was made up as follows: Puddling pig, 21,020 tons; casting pig, 40,320 tons; and steel pig, 967,710 tons.

INTERNAL STRESSES IN HEAT-TREATED AXLES.*

BY

H. V. WILLE, M.E.,

The Baldwin Locomotive Works, Philadelphia.

Member of the Institute.

A SERIES of experiments was conducted upon two 10" driving axles about six feet long for the purpose of determining the internal stresses in forgings after heat treatment. The axles were hollow bored with a 3" hole and were heated to 1500° and quenched in oil and then immediately removed to an annealing furnace and annealed at 1200°. The object of these tests was to determine the magnitude of stresses in the axles due to heat treatment.

MATERIAL.

The axles were made of open hearth plain carbon steel of the following chemical analysis and physical properties.

HEAT NUMBER 71429.

Carbon .....	.50
Manganese .....	.44
Phosphorus .....	.037
Sulphur .....	.038
Elastic limit	54000
Tensile strength	88500
Elongation in 2"	24 %
Reduction of area	43.5%

The axles were made from blooms of the same size and were given the same reduction and number of heats in forging.

HEAT TREATMENT.

Both axles were heated to the same temperature for quenching and drawing back and were held in the furnace the same length of time for these operations; both were quenched in the same oil tank, the *difference* in the *treatment* being the *method*

* Communicated by the Author.

of quenching. One axle was lowered *horizontally*, the other *vertically*, into the oil.

The heating temperatures for both axles were as follows:

(1) *Heated* to 1600 ° F., allowing six hours for the temperature to rise to this point and held at this temperature for another six hours.

(2) *Quenched* in oil until practically cold.

(3) *Drawn* at 1200 ° F., allowing, as before, six hours to come to this temperature, and held at this temperature for six hours. *Removed from furnace* and allowed to cool naturally in the air inside the hammer shop.

DESIGNATION OF AXLES.

The axle which had been quenched horizontally was marked "H."

The axle which had been quenched vertically was marked "V."

PORTIONS EXPERIMENTED UPON.

Each axle was cut in half at the works of the manufacturer, after heat treatment, one-half being cut up into tensile test specimens, and the other half reserved for these experiments.

The end of axle "V" that went into the oil first was employed for making these experiments.

METHODS OF TEST.

The strains in certain portions of the axle (see Fig. 1) were obtained by carefully measuring specimens before and after their removal from the axles. The stresses were calculated from the measured strains.

Two methods, (a) and (b), hereafter described, were used to obtain the strains:

(a) The measurement of rings cut from cross-sections of the forgings.

(b) The measurement of straight pieces taken out of the axles in three directions: tangentially, radially, and parallel to the axis of the forgings.

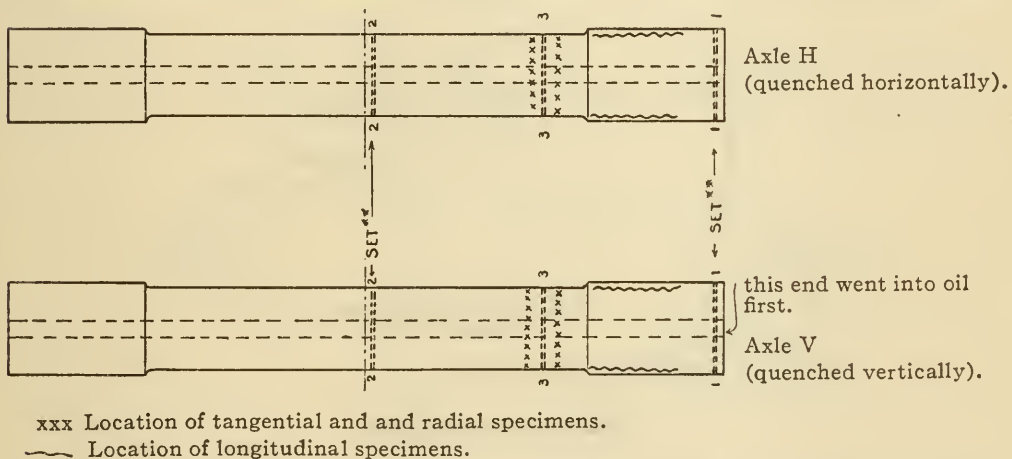
Method (a).—This method, which was used at the Watertown Arsenal some years ago by the Ordnance Department,

U. S. A., for the determination of stresses in gun forgings, is as follows:

Concentric rings are removed from the forgings and their diameters and thicknesses measured on several points, before and after removal. From the diameters and thicknesses of attached rings the mean diameter can be found, and from the diameters and thicknesses of the rings after removal their mean diameter is again found, and from the differences between these results before and after removal, assuming that the rings remain circular, the strains and stresses are calculated. The special application of this method to our experiments was as follows:

(1) Four rings were removed at each of the three sections, 1,

FIG. 1.



2, and 3, shown in Fig. 1. The rings taken out at each section were known as sets: set No. 1 coming from the end of the wheel-fit; set No. 2 coming from what was approximately the middle of the axle; and set No. 3 midway between 1 and 2.

Each of the rings was numbered, starting with the smallest ring as No. 1, and were removed as follows: The axles were turned cylindrically for a short distance and four diameters of this cylindrical portion, 45° apart, were measured with outside micrometer calipers (these measurements being known as "original values").

(2) A concentric groove "G" (see Fig. 2) was cut, and the same four diameters again measured (these measurements were known as "attached values").

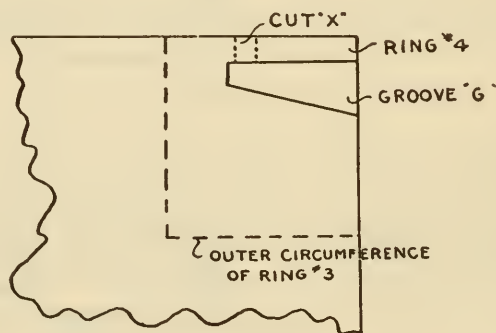
(3) A ring was removed by cutting off at "X" (Fig. 2), and the same diameters measured again (these measurements known as "detached values").

(4) The thickness of the rings was measured at the end of each of these diameters, and from these measurements the mean diameter of the ring was determined, for the "attached" and "detached" values.

Generally the mean diameters of the rings at the four points were found to be larger after removal than before, but in a number of cases this was not true, indicating that the ring did not remain circular but assumed some shape which it was not possible to plot from the measurements of diameters.

After the outside (the No. 4) ring had been removed, the axle was turned down to the outer diameter of the next (the

FIG. 2.



Method of removing rings.

No. 3) ring, and the process of measuring repeated. In this manner twelve rings were removed from each axle. (See Figs. 1, 2, and 5a.)

From all of these measurements it was expected to average the strains and calculate the stresses released by the undercutting and removal of the rings.

Method (b).—The measurement of changes in length of specimens by means of a comparator is a standard and one used extensively, but the method developed here by measuring small changes in length by means of one microscope and a *standard of comparison* has not been used before, so far as I know. The use of the comparator for a purpose similar to our investigation is described in "The International Proceedings of Metallography" (January 16, 1911), by Professors Heyn and Bauer.

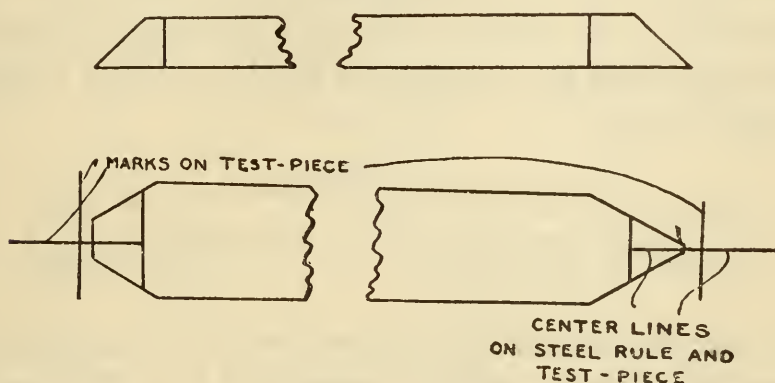
The use of a *standard of comparison* of 15 inches or more in length would probably enable one to realize a degree of accuracy as high as that obtained by Professors Heyn and Bauer with a comparator.

The measurement of straight specimens under this method is as follows:

Specimens are laid out on a smoothly finished surface and marks made on them along the ends of a hardened steel scale of a definite length by means of a very fine scribe.

A *standard of comparison*, slightly shorter than the steel scale and made of the same material as specimens to be measured and shaped, as shown in Fig. 3, is placed between the marks on the specimens.

FIG. 3.



Standard of comparison.

A microscope with Filar micrometer attachment is focused on the end of the specimen, and the distance between each end of the *standard of comparison* and the marks on the test piece is measured before the specimen is cut out.

In addition to the marks perpendicular to the axis of the specimen a line is drawn parallel to the axis, and there are also longitudinal marks on the ends of the *standard of comparison*, which, in measuring, are placed on the longitudinal line of the specimen, in order to always have it in the same position with respect to the axis of the specimen to be measured.

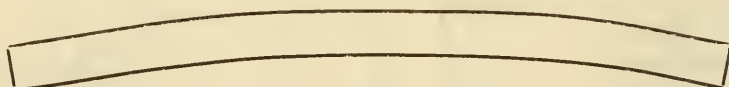
After the specimen is removed the *standard of comparison* is again placed on it and the operation of measuring is repeated. It makes no difference whether the *standard* is in the same posi-

tion with respect to the end marks as it was before or not, for the reason that the total distance between the ends of the *standard* and the marks is what we are considering, and the difference between the measurements before and after cutting out is the strain in a specimen of a length equal to the original distance between the marks, assuming of course that the length of the *standard of comparison* is the same in each measurement.

For this reason, the *standard* should be made, as noted above, of the same material as the part to be measured in order to avoid complications which would arise due to differences in temperature.

All of the measurements in our experiments were made at as nearly as possible the same temperature, and precautions were taken to minimize changes in temperature during the measurements.

The stresses in the specimens are never distributed entirely symmetrically in the cross-section and the unsymmetrical distribution may cause the specimen to bend, as shown exaggerated in the sketch below,



in which case the measurement, after removal of the piece, would not be entirely correct, unless it were held in a clamping device which would keep it straight. If such a device is not used, the amount of the bend must be measured and correction made for the shortening of the specimen. Such device was not found necessary in these experiments, as there was no bending that could be noticed at all in any of the specimens, with the exception of the longitudinal pieces cut from the inside of each axle (see Fig. 5—the cross hatch portion next the hole). These results have been corrected for this condition. The probable error of measurement made by the method above described, using a magnification of fifty diameters, is about one ten-thousandth of an inch.

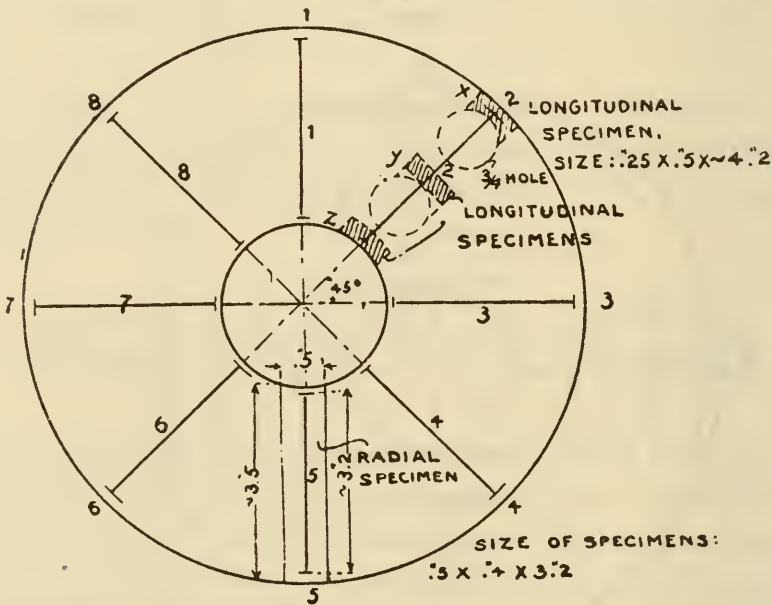
The results of our experiments under method (*b*), which are given in the following tables and curves, are based on measurements of fifty test pieces from each axle, as follows:

specimens, namely, B 1-1 and A 1-5 being spoiled, all of the other test pieces were cut out on the miller.

It was found impossible to remove tangential pieces A 1-1 or A 2-1 from either axle on account of a lack of space. (See Figs. 4 and 5 for location of specimens.)

In removing the longitudinal test pieces, the holes in the axles were bored out slightly larger (trued up) and the circumferences of the axles and of the holes in the axles were ground cylindrically for a distance of about 8 inches. The specimens were laid out first on the outside of this cylindrical portion and measured as

FIG 5.



Location of radial and longitudinal specimen.

described above, using a longer scale and *standard of comparison*. Three-quarter-inch holes were then drilled parallel to the axis (see Fig. 5) and the pieces milled out.

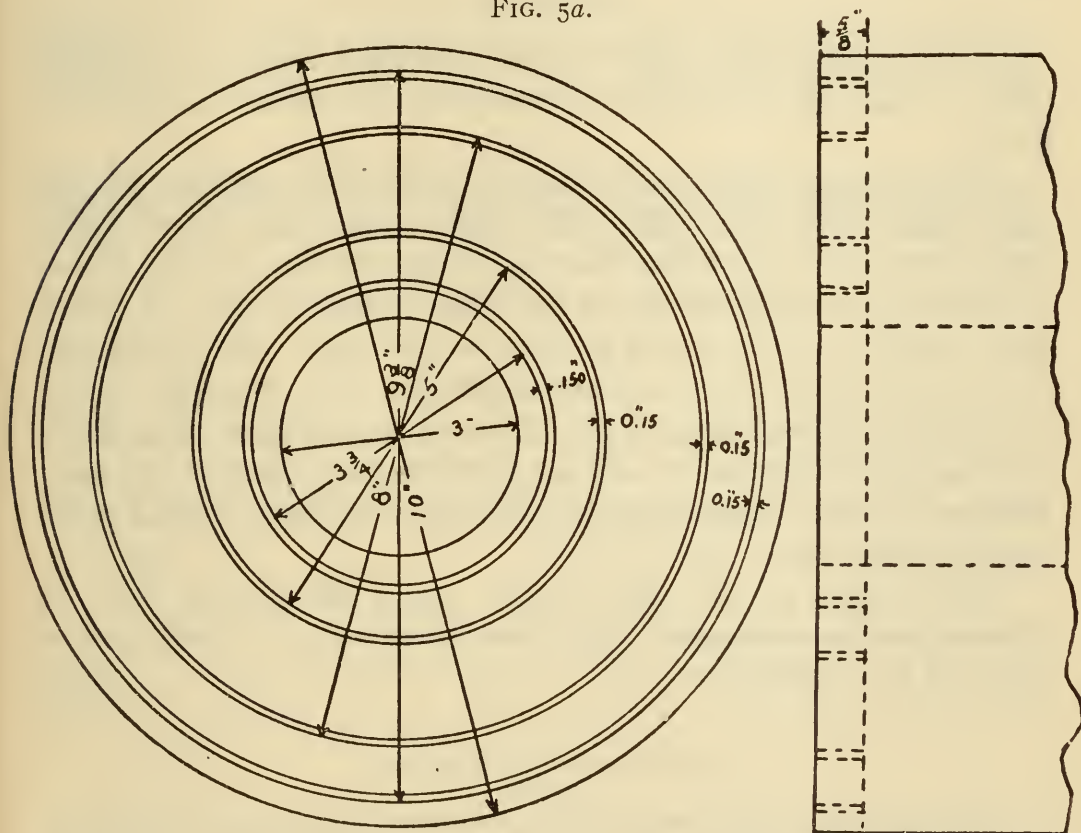
The remainder of the axle was then turned down to the diameter midway between the original outside diameter and the diameter of the hole and the operation repeated for the longitudinal specimens midway between the centre and the outside. The longitudinal specimens from the inside were obtained in the same manner.

In all cases, after removal, the specimens were brought to the Test Department and placed with the *standard of comparison*

and the steel scale and allowed to come to the same temperature. They were handled with woollen gloves and every precaution taken to maintain them at the same temperature.

Below is shown the method of calculating the strains and stresses and the results of the tests:

FIG. 5a.



Position of rings in method (a).

Calibration of Filar Micrometer.—Using a 32 mm. objective and a glass scale with divisions of .01 of a millimetre, it was found that one interval of the drum of the Filar micrometer is equal to .0002215 mm., or .0000872 of an inch. (Personal value of E. Vogt.)

Calculations.—For a distance of 1 cm. between the marks the stresses expressed in Kg./cm. Sq./ 467.2 *i*.

Where i is the strain of specimens expressed in intervals of the drum of Filar micrometer, from which

$$\text{Lbs./Sq. in.} = 6645 \times i$$

and the stress in the distance measured is

$$\text{Lbs./Sq. in.} = \frac{6645 \times i}{n}$$

where n = original distance in cm. between the marks on the specimens.

RESULTS.

The final results obtained under method (a) are given in table 1, while the detailed measurements are shown in tables A to E.

The stresses here are calculated from the changes of the mean diameters of the rings, as described, and are, as stated there, dependent on the condition that the rings remain circular, which we definitely determined is not the case. This method can therefore only give us the mean stresses in the rings, which does not give us an idea of the true state of affairs. For example, if two of the diameters decreased to the same extent that two others increased, this method would not indicate any internal stresses; whereas, in fact, there might be stresses of opposite sign of quite considerable value.

The results of the experiments, using the method (b) of microscopic measurement, are given in tables 2, 3, and 4, and curves 6 to 9, inclusive.

CURVES AND AVERAGES.

The averages of the stresses have been calculated and are given in the tables following.

TABLE 1.¹

Ring No.	Mean of stresses, as calculated from mean strain in detached ring of set No.							
	1		2		3		Mean	
	Axle H	Axle V	Axle H	Axle V	Axle H	Axle V	Axle H	Axle V
1	27250	40550	30200	29800	24900	23700	27450	31350
2	12580	14700	37300	9810	16260	15560	22047	13357
3	12100	3100	8730	17220	13200	9480	11343	9933
4	21800	8460	20280	23050	17900	18880	19993	16797
Mean	18433	16703	24128	19970	18065	16905	20208	17859

¹ All in compression.

TABLE 2.
STRESSES AND STRAINS IN LONGITUDINAL SPECIMENS AS PER FIGS. 1 AND 5.

Location of set	SPECIMEN NUMBER.								Mean
	1	2	3	4	5	6	7	8	
Outside.....	+14600	+18500	+24900	+22800	+ 9200	+16700	+27300	+19700	+19210
Middle.....	- 4500	+ 2900	- 7100	- 4000	- 200	+ 1200	- 60	- 2600	- 1862.5
Inside.....	+ 900	- 3800	- 3800	- 2900	- 500	- 5500	- 2900	- 1700	- 2525

Axle H.

Outside.....	+11100	+17700	+10600	+15300	+16100	+13400	+16400	+ 6400	+13375
Middle.....	+ 1700	- 300	- 2400	- 3200	- 6800	- 5500	- 3200	- 900	- 2575
Inside.....	- 6500	- 6100	- 8700	- 2400	- 3700	- 7000	- 6700	- 5100	- 5775

+ means compression } in the original specimen.
- means tension

TABLE 2-A.
STRAINS OF SPECIMENS IN INTERVALS OF DRUM AS PER FIGS. 1 AND 5.

Location of set	SPECIMEN NUMBER.							
	1	2	3	4	5	6	7	8
Outside.....	+23.4	+29.7	+40.0	+36.6	+14.8	+26.8	-43.9	+31.7
Middle.....	- 7.2	+ 4.7	-11.4	- 6.4	- .3	+ 1.9	- .1	- 4.2
Inside.....	+ 1.4	- 6.1	- 6.1	- 4.6	- .8	- 8.8	- 4.7	- 2.7

Axle H.

Outside.....	+17.8	+28.4	+17.0	+24.6	+25.8	+21.5	+26.3	+10.3
Middle.....	+ 2.7	- .5	- 3.8	- 5.1	-10.9	- 8.8	- 5.1	- 1.4
Inside.....	-10.4	- 9.8	-13.9	- 4.0	- 5.9	-11.3	-10.7	- 8.2

m = No. of cm. between original marks on specimens = 10.67.

TABLE 3.
STRESSES OF RADIAL SPECIMENS DISTRIBUTED EQUALLY AROUND THE AXIS BY 45°, AS PER FIGS. 1 AND 5.

Axle	SPECIMEN NUMBER.								Average
	1	2	3	4	5	6	7	8	
H	+11900	+10200	+ 7300	+ 6900	+12200	-10400	- 2400	+10000	+ 5713
V	+ 4600	+ 9400	+14700	+13900	+15500	+13400	+ 5300	+16500	+11663

TABLE 3-A.

STRAINS OF RADIAL SPECIMENS, AS PER FIG. 5, IN INTERVALS ON DRUM OF FILAR MICROMETER.

Axle	SPECIMEN NUMBER.							
	1	2	3	4	5	6	7	8
H	+14.2	+12.2	+ 8.7	+ 8.3	+14.6	-12.4	- 2.9	+12.0
V	+ 5.5	+11.2	+17.6	+16.6	+18.5	+16.0	+ 6.3	+19.7

n = number of cm. between original marks on specimens = 7.97.

TABLE 4.

STRESSES IN POUNDS PER SQUARE INCH OF THE TANGENTIAL SPECIMENS, AS PER FIGS. 1 AND 4.

No. of specimen.	Axle H					Axle V				
	A1	A2	B1	B2	Average	A1	A2	B1	B2	Average
1	.....	.....	*	+ 5300	+ 5300	.....	.....	+27300	+18800	+23050
2	+ 2700	+ 6500	+ 2500	- 1500	+ 2550	- 1100	+ 900	+ 7000	+ 7300	+ 3525
3	+ 9400	+10500	- 900	- 3500	+ 3875	+ 8400	-12100	+ 3300	+ 1400	+ 250
4	+ 8400	+10600	+ 8500	+ 5600	+ 8275	+17700	+ 5500	+10000	+ 3100	+ 9750
5	*	+12300	+17400	+18600	+16100	+29200	+21400	+28500	+28700	+27450
Average.	+ 6833	+ 9975	+ 6875	+ 4900	+ 7183	+13550	+ 3925	+15220	+11860	+11972

* Specimen spoiled during cutting operations in the shop.
+ Compression in the original specimen.
- Tension in the original specimen.

TABLE 4-A.

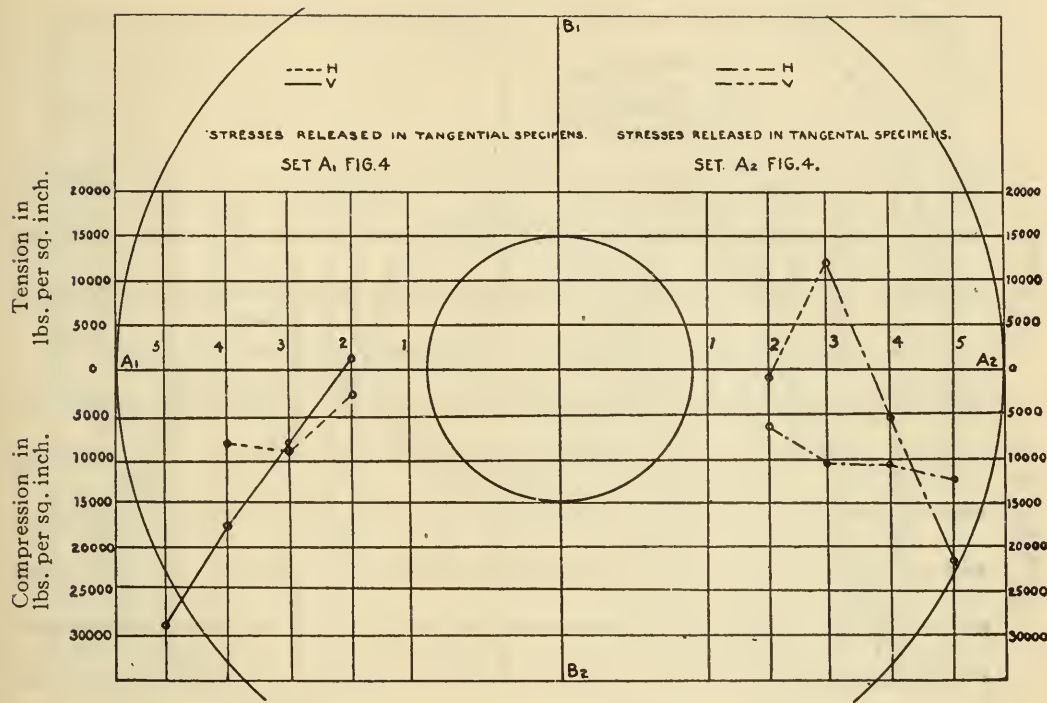
STRAINS OF THE TANGENTIAL SPECIMENS, AS PER FIG. 4, IN INTERVALS ON DRUM OF FILAR MICROMETER.

No. of specimen	Axle H (n = 7.97).				Axle V (n = 7.66).			
	A1	A2	B1	B2	A1	A2	B1	B2
1	....	....	....	6.3	....	....	+31.5	+21.6
2	+ 3.2	+ 7.8	+ 3.0	- 1.8	- 1.3	+ 1.0	+ 8.1	+ 8.4
3	+11.2	+12.6	- 1.1	- 4.2	+ 9.7	-13.9	+ 3.8	+ 1.6
4	+10.1	+12.7	+10.2	+ 6.7	+20.4	+ 6.3	+11.5	+11.3
5	....	+14.7	+20.8	+22.3	+33.7	+24.7	+32.8	+33.1

n = number of cm. between original marks on specimens = 7.97.

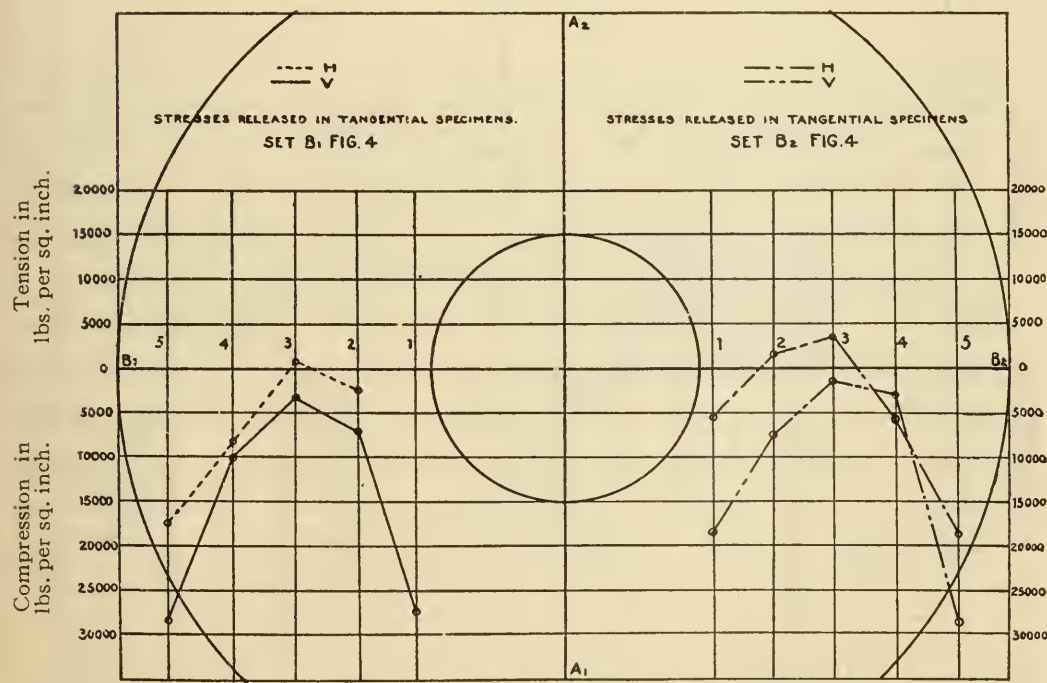
Fig. 6 shows the stresses released in the tangential specimens, plotted on the diameter A-1 A-2 (Fig. 4); Fig. 7 shows the stresses released in the tangential specimens, plotted on the diameter B-1 B-2 (Fig. 4) ; Fig. 8 shows these two curves super-

FIG. 6.



Stresses released in tangential specimen plotted in diameter A1 A2, Fig. 4.

FIG. 7.



Stresses released in tangential specimen plotted in diameter B1 B2, Fig. 4.

FIG. 8.

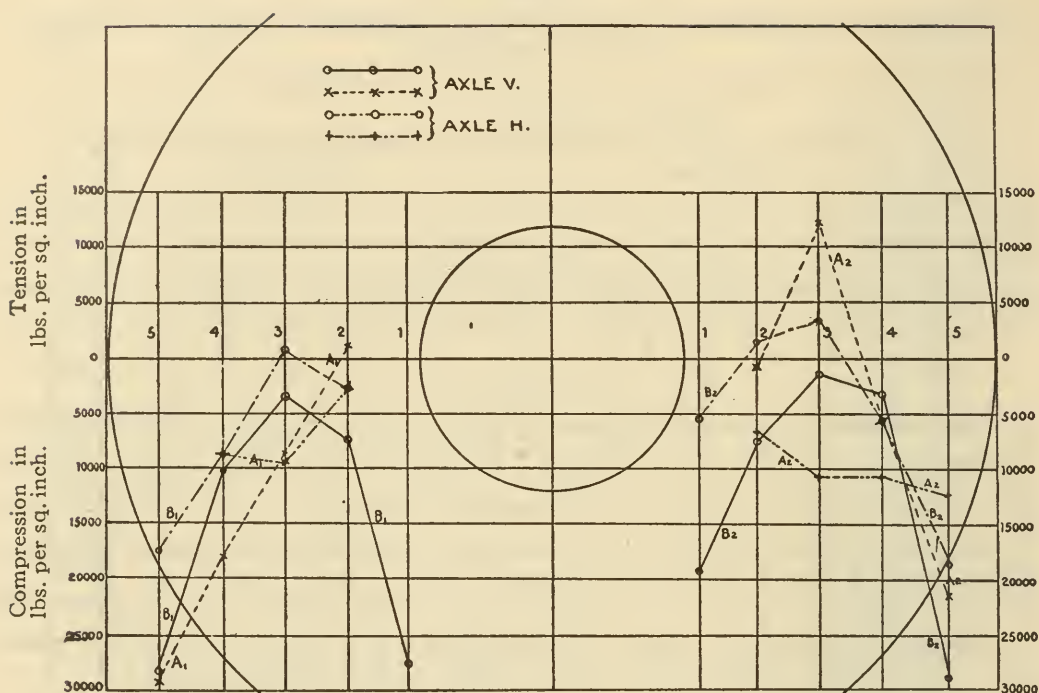
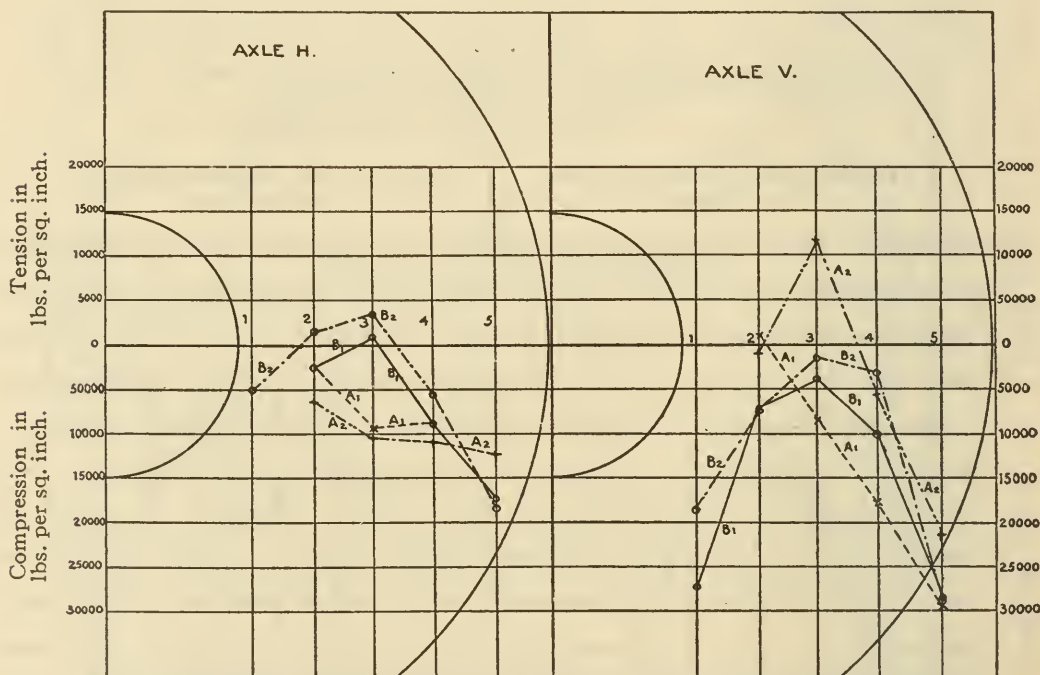
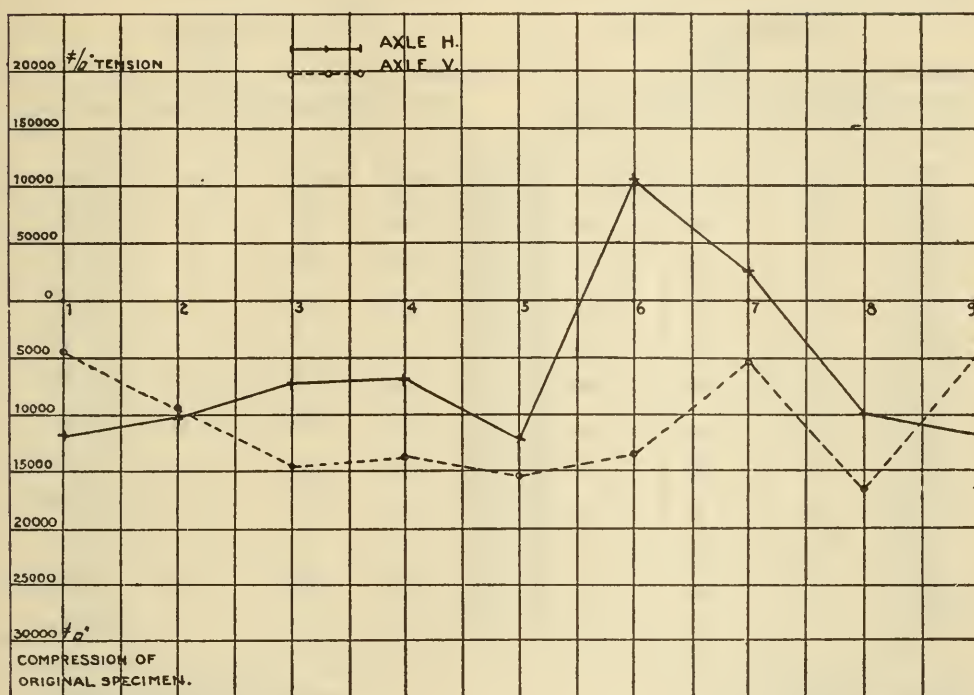


FIG. 9.



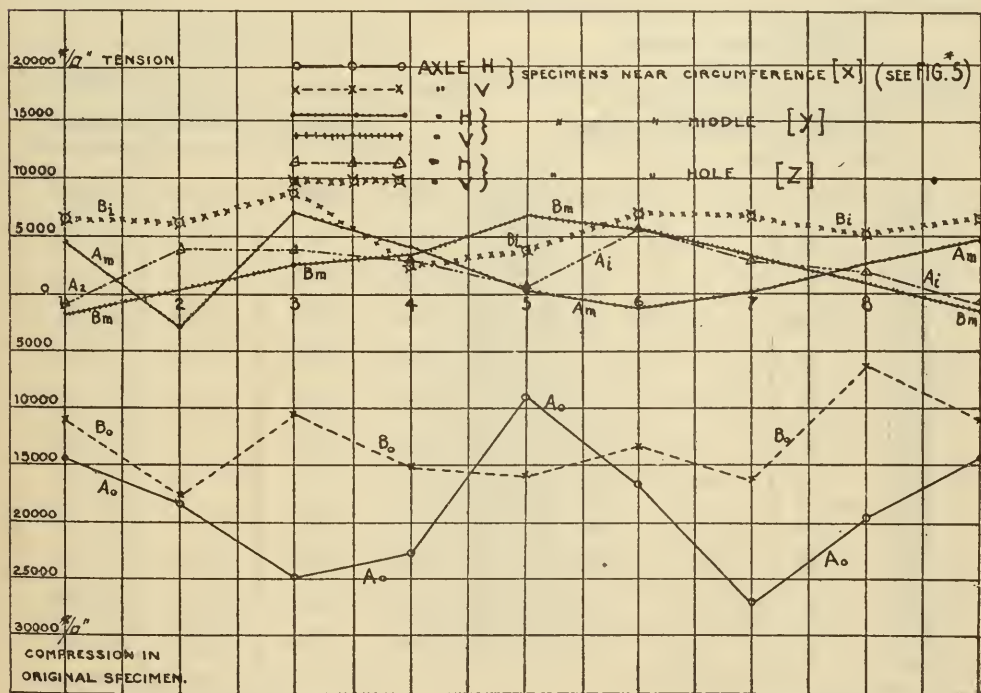
imposed, although the specimens are located on a centre line at an angle of 90 with each other. We can see from this plot that the stresses, and especially the difference in the stresses on

FIG. 10.



Internal stresses in two 10" axles as found in radial specimens.
Average results from similar positions.

FIG. II.



Internal stresses in two 10" axles as found in longitudinal specimens (see Fig. 5).

AXLE: H

SET 1

RING 1

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A	3.7036	3.7053	3.7083	.1597 90	.1594	3.8630	3.8647	3.8677
	40	66	90	.95 98	96	36	62	86
	39	75	97	.93 97	95	34	70	92
	30	64	67	.88 93	91	21	55	58
B	32	58	55	.89 92	90	22	48	45
	33	62	66	.93 95	94	27	56	60
	41	48	34	.90 84	87	28	35	21
	50	53	40	.96 88	92	42	45	32
C	40	47	35	.92 90	91	31	38	26
	48	55	95	.93 89	91	39	46	86
	30	84	106	.93 97	95	25	79	701
	32	81	04	.95 96	95	27	76	699
Mean of diameter:.....						3.86302	3.86548	3.86653
Mean of total strain:.....						#/□	.00246	.00351
Mean of total stress:.....							19100	27250

AXLE: H

SET 1

RING 3

Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A	8.0054	8.0080	8.0088	.1553 1572	.1563	7.8491	7.8517	7.8525
	60	85	82	.1562 58	.1560	500	25	22
	60	75	86	.55 65	.1560	500	15	26
	66	80	60	.56 64	.1560	506	20	00
B	58	72	72	.58 66	.1562	496	10	10
	62	75	78	.60 60	.1560	502	15	18
	70	94	140	.66 56	.1561	509	33	79
	62	103	131	.58 63	.1561	501	42	70
C	62	120	143	.60 58	.1559	503	61	84
	58	059	084	.72 64	.1568	490	491	16
	66	63	76	.58 66	.1562	504	501	14
	60	69	78	.65 55	.1560	500	509	18
Mean of diameter:.....						7.85002	7.85199	7.85318
Mean of total strain:.....						#/□	.00197	.00316
Mean of total stress:.....							7500	12100

AXLE: H

SET I

RING 2

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A	5.0888	5.0889	5.0908	.1576 88	.1582	5.2470	5.2471	5.2490
	84	902	02	84 90	87	71	89	89
	92	906	06	82 83	83	75	89	89
	85	906	20	92 80	86	71	92	506
B	97	898	12	80 78	79	76	77	491
	91	900	14	80 84	82	73	82	96
	95	12	22	76 84	80	75	92	502
	90	03	30	80 88	84	74	87	14
C	93	07	28	82 83	83	76	90	11
	76	03	02	90 84	87	63	90	489
	90	893	896	76 82	79	69	72	75
	88	97	93	83 81	82	70	79	75
Mean of diameter:.....						5.24719	5.24842	5.24939
Mean of total strain:.....							.00123	.00220
Mean of total stress:.....						#/□	7030	12580

AXLE: H

SET I

RING 4

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A	9.3568	9.3608	9.3704	.1598 1604	.1601	9.1967	9.2007	9.2103
	76	34	708	.1600 1599	.1600	76	34	108
	72	30	695	.1605 1600	.1602	70	28	093
	64	558	574	.1598 1608	.1603	61	.1955	.1971
B	70	68	568	.1604 1604	.1604	66	64	64
	72	66	570	.1602 1606	.1604	68	62	66
	58	608	636	.1596 1608	.1602	56	.2006	.2034
	68	04	642	.1604 1598	.1601	67	03	41
C	74	22	640	.1600 1602	.1601	73	21	39
	64	588	636	.1592 1598	.1595	69	.1993	41
	72	96	624	.1604 1606	.1605	67	91	19
	68	90	630	.1598 1603	.1600	68	90	30
Mean of diameter:.....						9.19673	9.19928	9.20341
Mean of total strain:.....							.00255	.00668
Mean of total stress:.....						#/□	8320	21800

AXLE: H

SET 2

RING 1

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	3.7043	3.7066	3.7120	{ _{1541 42}	.1541	3.8584	3.8607	3.8661
B { _{1 2}	38	55	65	{ _{.1545 33}	.1539	77	594	04
C { _{1 2}	42	56	76	{ _{.1541 40}	.1541	83	597	17
D { _{1 2}	53	69	70	{ _{.1542 42}	.1542	95	611	12
Mean of diameter:.....						3.85847	3.86023	3.86235
Mean of total strain:.....							.00176	.00388
Mean of total stress:.....						#/□	13700	30200

AXLE: H

SET 2

RING 3

Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { _{1 2}	8.0010	8.0016	8.0035	{ _{.1590 92}	.1591	7.8419	7.8425	7.8444
B { _{1 2}	7.9990	03	12	{ _{88 96}	.1592	398	11	20
C { _{1 2}	93	00	06	{ _{93 90}	.1591	402	09	15
D { _{1 2}	8.0005	17	36	{ _{92 90}	.1591	414	26	45
Mean of diameter:.....						7.84082	7.84177	7.84310
Mean of total strain:.....							.00095	.00228
Mean of total stress:.....						#/□	3630	8730

AXLE: H

SET 3

RING 1

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { _{1 2}	3.6996	3.7020	3.7035	{ _{1519 26}	.1523	3.8519	3.8543	3.8558
B { _{1 2}	.7000	12	30	{ _{25 28}	.1526	26	38	56
C { _{1 2}	08	16	29	{ _{30 22}	.1526	34	42	55
D { _{1 2}	05	03	43	{ _{26 27}	.1526	31	29	69
Mean of diameter:.....						3.85275	3.85380	3.85595
Mean of total strain:.....							.00105	.00320
Mean of total stress:.....						#/□	8180	24900

MEASUREMENTS OF RINGS.

[INTERNAL STRESSES]

AXLE: H

SET 2

RING 2

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	5.0198	5.0214	5.0270	{ ₁₄₈₀ 85	.1483	5.1681	5.1697	5.1753
B { ₁ 2	80	12	05	{ ₈₃ 87	.1485	65	97	690
C { ₁ 2	76	15	64	{ ₈₀ 83	.1482	58	97	746
D { ₁ 2	200	40	72	{ ₈₂ 81	.1482	82	722	754
Mean of diameter:.....						5.16715	5.17033	5.17358
Mean of total strain:.....							.00318	.00643
Mean of total stress:.....						#/□	18450	37300

AXLE: H

SET 2

RING 4

Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	9.4021	9.4083	9.4056	{ ₁₅₃₀ 50	.1540	9.2481	9.2543	9.2516
B { ₁ 2	05	43	102	{ ₃₀ 32	.1531	74	12	71
C { ₁ 2	10	32	095	{ ₂₈ 26	.1527	83	05	68
D { ₁ 2	20	58	053	{ ₃₅ 30	.1532	88	26	21
Mean of diameter:.....						9.24815	9.25215	9.25440
Mean of total strain:.....							.00400	.00625
Mean of total stress:.....						#/□	12980	20280

AXLE: H

SET 3

RING 2

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	5.0105	5.0109	5.0136	{ ₁₅₄₀ 47	.1544	5.1649	5.1653	5.1680
B { ₁ 2	06	21	28	{ ₄₉ 47	.1548	54	69	76
C { ₁ 2	00	12	19	{ ₅₁ 49	.1550	50	62	69
D { ₁ 2	03	08	43	{ ₄₈ 46	.1547	50	55	90
Mean of diameter:.....						5.16508	5.16598	5.16788
Mean of total strain:.....							.00090	.00280
Mean of total stress:.....						#/□	5230	16260

AXLE: H			SET 3			RING 3		
Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A {1 2}	7.9901	7.9912	7.9928	{1532 34}	.1533	7.8368	7.8379	7.8395
B {1 2}	02	906	47	{32 30}	.1531	71	75	416
C {1 2}	00	899	38	{31 39}	.1535	65	64	403
D {1 2}	04	926	32	{33 41}	.1537	67	89	395
Mean of diameter:.....						7.83678	7.83768	7.84023
Mean of total strain:.....							.00090	.00345
Mean of total stress:.....						#/□	3450	13200

AXLE: V			SET 1			RING 1		
Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A {1 2}	3.7060	3.7071	3.7100	{.1554 49}	.1552	3.8612	3.8623	3.8652
B {1 2}	65	84	133	{58 61}	.1559	24	43	92
C {1 2}	60	96	121	{53 60}	.1557	17	53	78
D {1 2}	55	60	095	{49 60}	.1555	10	15	50
Mean of diameter:.....						3.86158	3.86335	3.86680
Mean of total strain:.....							.00177	.00522
Mean of total stress:.....						#/□	13750	40550

AXLE: V			SET 1			RING 3		
Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A {1 2}	7.9945	7.9940	7.9932	{1560 85}	.1572	7.8373	7.8368	7.8360
B {1 2}	50	51	90	{75 70}	.1573	77	78	417
C {1 2}	47	65	70	{76 76}	.1576	71	89	394
D {1 2}	50	52	32	{80 76}	.1578	72	74	354
Mean of diameter:.....						7.83732	7.83772	7.83813
Mean of total strain:.....							.00040	.00081
Mean of total stress:.....						#/□	1530	3100

AXLE: H			SET 3			RING 4		
Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A {1 2}	9.3695	9.3710	9.3737	{ 1602 01 }	.1601	9.2094	9.2109	9.2136
B {1 2}	97	35	770	{ 1597 604 }	.1601	096	34	169
C {1 2}	95	52	795	{ .1590 .1600 }	.1595	100	57	200
D {1 2}	97	13	702	{ .1591 99 }	.1595	102	18	107
Mean of diameter:.....						9.20980	9.21295	9.21530
Mean of total strain:.....							.00315	.00550
Mean of total stress:.....						#/□	10250	17900

AXLE: V			SET 1			RING 2		
Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A {1 2}	5.0180	5.0212	5.0215	{ .1430 28 }	.1429	5.1609	5.1641	5.1644
B {1 2}	82	80	191	{ 28 24 }	.1426	08	06	17
C {1 2}	74	96	226	{ 24 36 }	.1430	04	26	56
D {1 2}	80	85	185	{ 22 32 }	.1427	07	12	12
Mean of diameter:.....						5.16070	5.16212	5.16323
Mean of total strain:.....							.00142	.00253
Mean of total stress:.....						#/□	8260	14700

AXLE: V			SET 1			RING 4		
Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached ed	Detached
A {1 2}	9.3767	9.3785	9.3803	{ 1544 40 }	.1542	9.2225	9.2243	9.2261
B {1 2}	67	770	780	{ 42 42 }	.1542	25	28	238
C {1 2}	67	765	744	{ 43 38 }	.1541	26	24	203
D {1 2}	67	802	845	{ 45 43 }	.1544	23	58	301
Mean of diameter:.....						9.22248	9.22383	9.22508
Mean of total strain:.....							.00135	.00260
Mean of total stress:.....						#/□	4390	8460

AXLE: V		SET 2				RING 1			
Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches			
	Original	Attached	Detached			Original	Attached	Detached	
A	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	3.4669	3.4716	3.4709	$\left\{ \begin{smallmatrix} 1461 \\ 73 \end{smallmatrix} \right\}$	.1467	3.6136	3.6183	3.6176
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	73	06	09	$\left\{ \begin{smallmatrix} 85 \\ 75 \end{smallmatrix} \right\}$	.1480	53	86	89
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	59	3.4681	3.4689	$\left\{ \begin{smallmatrix} 99 \\ 82 \end{smallmatrix} \right\}$	91	50	72	80
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	99	3.4745	3.4737	$\left\{ \begin{smallmatrix} 59 \\ 71 \end{smallmatrix} \right\}$	65	64	3.6210	3.6202
B	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	93	29	36	$\left\{ \begin{smallmatrix} 75 \\ 88 \end{smallmatrix} \right\}$	81	74	10	17
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	82	03	18	$\left\{ \begin{smallmatrix} 92 \\ 90 \end{smallmatrix} \right\}$	91	73	3.6194	09
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	81	23	10	$\left\{ \begin{smallmatrix} 61 \\ 71 \end{smallmatrix} \right\}$	66	47	89	3.6176
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	86	15	10	$\left\{ \begin{smallmatrix} 78 \\ 97 \end{smallmatrix} \right\}$	88	74	3.6203	98
C	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	77	3.4693	3.4695	$\left\{ \begin{smallmatrix} 95 \\ 1504 \end{smallmatrix} \right\}$	99	76	3.6192	94
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	77	3.4735	3.4730	$\left\{ \begin{smallmatrix} 1461 \\ 57 \end{smallmatrix} \right\}$	59	36	94	89
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	83	21	23	$\left\{ \begin{smallmatrix} 65 \\ 76 \end{smallmatrix} \right\}$	71	54	92	94
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	63	3.4681	06	$\left\{ \begin{smallmatrix} 91 \\ 85 \end{smallmatrix} \right\}$	88	51	75	94
Mean of diameter:.....						3.61573	3.61927	3.61932	
Mean of total strain:.....						#/□	.00344	.00359	
Mean of total stress:.....							28500	29800	

AXLE: V		SET 2				RING 3			
Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches			
	Original	Attached	Detached			Original	Attached	Detached	
A	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	7.9922	7.9938	7.9987	$\left\{ \begin{smallmatrix} .1518 \\ 22 \end{smallmatrix} \right\}$	.1520	7.8402	7.8418	7.8467
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	37	47	90	$\left\{ \begin{smallmatrix} 40 \\ 26 \end{smallmatrix} \right\}$	33	04	14	57
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	57	62	90	$\left\{ \begin{smallmatrix} 43 \\ 27 \end{smallmatrix} \right\}$	35	22	27	55
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	36	53	98	$\left\{ \begin{smallmatrix} 16 \\ 30 \end{smallmatrix} \right\}$	23	7.8413	30	75
C	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	63	63	8.0001	$\left\{ \begin{smallmatrix} 24 \\ 43 \end{smallmatrix} \right\}$	34	7.8430	30	68
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	73	74	01	$\left\{ \begin{smallmatrix} 35 \\ 44 \end{smallmatrix} \right\}$	39	33	34	61
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	25	26	19	$\left\{ \begin{smallmatrix} 16 \\ 17 \end{smallmatrix} \right\}$	17	09	10	7.8503
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	51	52	21	$\left\{ \begin{smallmatrix} 25 \\ 27 \end{smallmatrix} \right\}$	26	25	26	7.8495
D	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	83	65	27	$\left\{ \begin{smallmatrix} 33 \\ 35 \end{smallmatrix} \right\}$	34	49	31	93
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	23	55	7.9957	$\left\{ \begin{smallmatrix} 18 \\ 28 \end{smallmatrix} \right\}$	23	00	32	34
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	45	74	62	$\left\{ \begin{smallmatrix} 27 \\ 39 \end{smallmatrix} \right\}$	33	12	41	29
	$\left\{ \begin{smallmatrix} 1 \\ 2 \end{smallmatrix} \right\}$	66	83	65	$\left\{ \begin{smallmatrix} 38 \\ 40 \end{smallmatrix} \right\}$	39	27	44	26
Mean diameter:.....						7.84188	7.84281	7.84638	
Mean of total strain:.....						#/□	.00093	.00450	
Mean of total stress:.....							3560	17220	

AXLE: V

SET 2

RING 2

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches			
	Original	Attached	Detached			Original	Attached	Detached	
A	{1 2}	4.8565	4.8581	4.8579	{.1365 70 81 .1406 .1399 .1415 .1373 69 98 73 .1422 .1381 63 75 98 1402 20 21 .1369 59 .1401 .1389 .1421 .1393}	.1368	4.9933	4.9949	4.9947
		69	73	62			.1392	61	66	55
	{1 2}	53	53	48	.1407	60	60	55	
		72	4.8608	4.8634	.1371	43	79	4.5005	
B	{1 2}	67	4.8586	4.8599	{.1386 73 .1422 .1381 63 75 98 1402 20 21 .1369 59 .1401 .1389 .1421 .1393}	.1386	53	72	9985
		72	82	92			.1401	73	83	93
	{1 2}	73	79	59	.1369	42	48	28	
		63	67	26	.1400	63	67	26	
C	{1 2}	44	60	18	{.1421 59 .1401 .1389 .1421 .1393}	.1421	65	81	39
		77	4.8607	4.8644			.1364	41	71	5.0008
	{1 2}	62	4.8582	07	.1395	57	77	5.0002	
		55	63	00	.1407	62	70	5.0007	
Mean of diameter:.....						4.99545	4.99685	4.99708	
Mean of total strain:.....						#/□	.00140	.00163	
Mean of total stress:.....							8400	9810	

AXLE: V

SET 2

RING 4

Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches			
	Original	Attached	Detached			Original	Attached	Detached	
A	1 2	9.3557	9.3591	9.3639	{.1500 .1492 .1500 .1491	.1496	9.2061	9.2095	9.2143
	1 2	57	70	28	{.1500 .1487 .1499 .1498	96	62	75	33
B	1 2	57	52	15	{.1500 .1487 .1499 .1498	93	63	58	21
	1 2	87	9.3624	73	{.1499 .1498 .1495 .1488	99	89	9.2126	75
C	1 2	87	05	40	{.1495 .1488 90 90	91	95	13	48
	1 2	87	9.3587	29	{90 90 81 81	90	97	9.2097	39
D	1 2	76	82	9.3788	{81 81 78 81	81	95	9.2101	9.2308
	1 2	76	80	86	{78 81 78 81	80	97	01	07
E	1 2	76	73	70	{78 81 87 85	79	96	9.2093	9.2290
	1 2	59	89	9.3520	{87 85 87 85	86	73	9.2103	9.2034
F	1 2	59	79	04	{87 85 88 85	86	73	9.2093	18
	1 2	59	60	94	{88 85	87	73	74	08
Mean of diameter:.....						9.20829	9.20958	9.21537	
Mean of total strain:.....						#/□	.00129	.00708	
Mean of total stress:.....							4080	23050	

AXLE: V

SET 3

RING 1

Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	3.7070	3.7072	3.7080	{ _{.1492} 1490	.1491	3.8561	3.8563	3.8571
B { ₁ 2	67	78	094	{ _{.1498} 1503	.1500	67	78	594
C { ₁ 2	65	83	094	{ ₁₅₀₆ 1502	.1504	69	87	598
D { ₁ 2	64	77	120	{ ₁₄₉₆ 1492	.1494	58	71	614
Mean of diameter:.....						3.85638	3.85748	3.85943
Mean of total strain:.....						#/□	.00110	.00305
Mean of total stress:.....							8560	23700

AXLE: V

SET 3

RING 3

Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	8.0050	8.0067	8.0103	{ ₁₅₂₇ 31	.1529	7.8521	7.8538	7.8574
B { ₁ 2	50	63	66	{ ₂₁ 13	.1517	33	46	49
C { ₁ 2	40	52	71	{ ₂₀ 26	.1523	17	29	48
D { ₁ 2	38	39	37	{ ₂₂ 26	.1524	14	15	13
Mean of diameter:.....						7.85212	7.85320	7.85460
Mean of total strain:.....						#/□	.00108	.00248
Mean of total stress:.....							4120	9480

MEASUREMENTS OF RINGS.

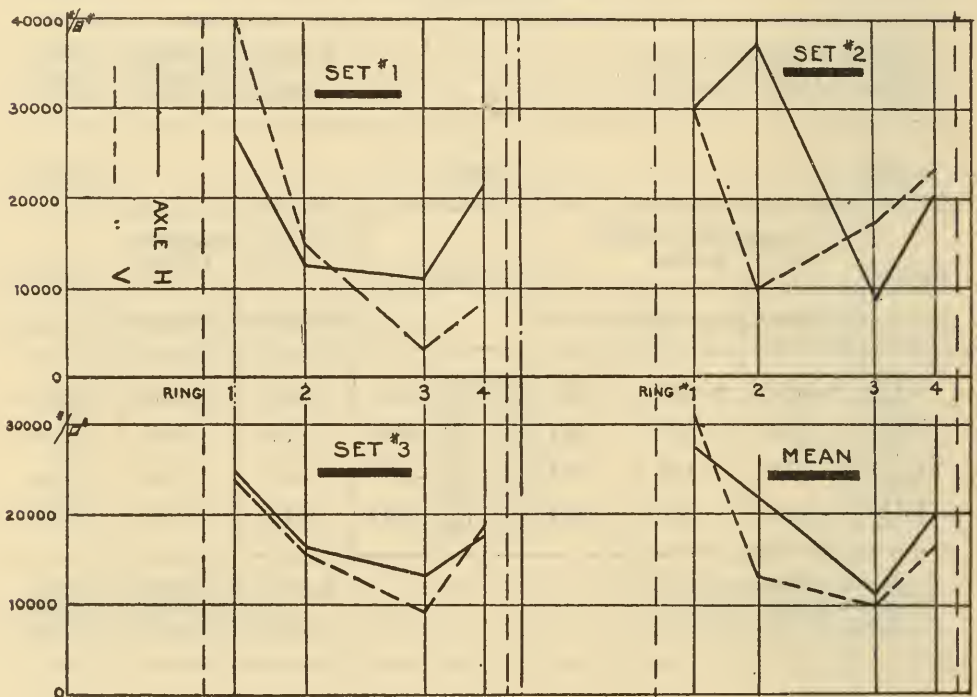
[INTERNAL STRESSES

AXLE: V			SET 3			RING 2		
Section	DIAMETER (inside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	5.0195	5.0196	5.0189	{ ₁₄₆₅ 58	.1462	5.1657	5.1658	5.1651
B { ₁ 2	92	198	244	{ ₇₂ 69	.1470	62	68	.1714
C { ₁ 2	90	196	210	{ ₇₂ 66	.1469	59	65	679
D { ₁ 2	91	213	232	{ ₅₈ 60	.1459	50	72	691
Mean of diameter:.....						5.16570	5.16658	5.16838
Mean of total strain:.....							.00088	.00268
Mean of total stress:.....						#/□	5110	15560

AXLE: V			SET 3			RING 4		
Section	DIAMETER (outside) Inches			Thickness		DIAMETER Inches		
	Original	Attached	Detached			Original	Attached	Detached
A { ₁ 2	9.3757	9.3772	9.3806	{ ₁₆₁₁ 19	.1615	9.2142	9.2157	9.2191
B { ₁ 2	50	776	821	{ ₁₀ 16	.1613	37	63	208
C { ₁ 2	52	801	755	{ ₁₃ 11	.1612	40	89	143
D { ₁ 2	41	757	850	{ ₂₂ 12	.1617	24	40	233
Mean of diameter:.....						9.21358	9.21623	9.21938
Mean of total strain:.....							.00265	.00580
Mean of total stress:.....						#/□	8630	18880

different points on the same longitudinal plane (parallel to the axis), are considerably greater in axle "V" than in axle "H." It is also to be noted with the vertically quenched axle that the stresses are a maximum near the outside surface and near the surface of the centre hole, and a minimum half way between these two points, while with the horizontally quenched axle the stresses do not tend to rise to so high a maximum near the centre hole.

FIG. 12.



Mean stresses as found by method (a).

One point, A 2-3, departs from the apparent rule, and this may have been due to a hard spot, some of which were noticed during machining.

The curves shown on Figs. 6, 7, and 8 have been replotted in Fig. 9. Here the values of the tangential specimens of each axle are plotted separately; furthermore the values of the specimens located in juxtaposition are shown revolved through 180. From this plot one can see even more clearly the greater stresses in axle "V" than in axle "H."

Fig. 10 is the plot of the stresses released in the radial specimens, and in this case it will be noted that one side of the section of axle "H" is shown in tension, the balance in compression;

whereas the stresses in axle "V" throughout the entire section are compressive.

Fig. 11 is the plot of the stresses released in the longitudinal specimens, and it will be noted that this is the only curve which shows the stresses in axle "H" to be greater than those of axle "V." The greater uniformity of stresses in axle "V" will be noted as well as the great difference between the stresses on the outside of both axles and the stresses in the middle and inside, the former being in compression while the middle and inside are slightly in tension.

Fig. 12 shows the stresses plotted from the three sets of rings and the mean of these curves, and it can be seen that they do not give as complete or satisfactory information as the curves obtained by method (b).

CONCLUSIONS.

1. Method (a) does not furnish desired results, as only relative values of the mean stresses in concentric rings can be obtained. Differences in stresses in the different parts of the rings, as was indicated by variations in the ring diameters, could not be obtained and plotted.

2. The stresses and their distribution can be found by method (b), as far as can be judged from the few tests made.

3. It is very possible and probable that the stresses are distributed more or less unsymmetrically throughout the length of the axle with respect to a plane perpendicular to the axis in the vertically quenched axle "V," and with respect to the axis itself in the case of the horizontally quenched axle "H." In order to investigate this it would be necessary to take specimens from both ends and the middle of the axle.

4. Fig. 9 shows that the stresses on different points of concentric rings differ considerably. It also shows that the influence of quenching in axle "V" (vertically quenched) is much greater than in axle "H" (horizontally quenched).

5. Fig. 9 also shows that the stress curves of the tangential specimens and longitudinal specimens in juxtaposition are similar.

6. All conclusions derived from the experiments must be used conservatively, on account of the small number of tests, and due to the fact that only one specimen of each kind and location was

measured. Nevertheless, it would appear that the heat treatment has had a much greater effect upon the vertically quenched than upon the horizontally quenched axle, in that the stresses are greater, and it would also appear that the stresses are somewhat more evenly distributed in the vertically quenched than in the horizontally quenched axle.

7. The results show that the problem of finding the internal strains in forgings can be satisfactorily solved, for practical purposes, by a method of microscopic measurement and valuable results obtained if a sufficient number of specimens be used.

Production of High Vacua by Means of Finely-divided Copper. T. R. MERTON. (*Chem. Soc. Journ.*, cv, 645.)—Finely-divided copper, which may be obtained by reducing a solution of a copper salt and is sold commercially as "precipitated copper," absorbs gases with great readiness, the vapor pressure of the gases thus absorbed being so small that under suitable conditions it may be used for the production of high vacua. A bulb containing a few grammes of the copper is sealed to the vessel to be exhausted, the vessel being then partially exhausted by means of an air-pump and the copper heated to about 250° C. When the air-pump is disconnected and the copper allowed to cool, the residual gases are rapidly absorbed. This absorption is not due to chemical combination, since the gases are liberated when the copper is heated. The carbon bands disappear first, then nitrogen, finally hydrogen, but helium does not appear to be absorbed appreciably. Diminution of the absorptive power of the copper follows (1) the use of an excessively high temperature, (2) repeated use, or (3) prolonged exposure to the mercury vapor from a mercury pump. Great care is necessary when the copper is being used for the first time, as the occluded gases may sometimes be evolved with such violence that the copper is blown through into the pump; consequently not more than one-third of the bulb should be filled with copper; and a short length of the tube connecting the bulb and the pump should be tightly packed with glass wool.

The Aluminum Cell Lightning Arrester. E. E. F. CREIGHTON. (*Amer. Inst. Elect. Eng. Proc.*, xxxiii, 795.)—A review of the present position of the aluminum cell as a form of protection against lightning. When used on direct current it is said to give the highest possible form of protection. On alternate current the following points are considered, *viz.*, dielectric spark log, dissolution of film, charging resistance, oscillations, damping, degrees of surge due to natural operations, and insulations which withstand these surges. On the whole, it is considered to be a device which is likely to do all the work which is thrown upon it.

THE EXUDATION OF ICE FROM STEMS OF PLANTS.*

BY

W. W. COBLENTZ, Ph.D.,

Associate Physicist, Bureau of Standards.

I. INTRODUCTION.

NOCTURNAL radiation is generally a passing of radiant energy from terrestrial substances into space. On a clear night the rate at which radiation passes outward from the earth's surface is very great, amounting to almost one-tenth of the solar constant. Of course, not all substances lose heat at this rate. This loss of heat by radiation produces peculiar formations of ice, some of which will now be mentioned.

Ground Ice.—The most familiar freak of ice formation occurs on bare, clayey soils which contain a certain (minimum) amount of moisture. If the moisture content of the soil falls below this minimum value (which no doubt varies for different soils), then evaporation occurs as rapidly as the moisture is brought to the surface (by capillary action) and no ice is formed. According to the writer's observations, the ice is formed in contact with a nucleus which may be a grain of sand, a small pebble, etc. The earthy material has a higher emissivity than the water, it cools the more rapidly and the water is frozen to the under side of the nucleus. As heat is lost, more ice is formed, and, as it accumulates, rises in columns, as is to be observed everywhere on cold mornings. The water is supplied by capillary movement in the soil, from the surface of which the ground ice may be readily lifted, since in freezing weather the ice is not frozen into the soil.¹ The general experience is to find the ground ice supporting a nucleus (say a grain of sand, or even large stones— $3 \times 1\frac{1}{2} \times 1$ inches in size). The nuclei may be thinly distributed. The writer has observed several large areas, $3 \times 1\frac{1}{2}$ feet, which did not contain nuclei, from which it appears that this type of ice formation can occur without having a nucleus (gravel, etc.) to start the refrigeration.

* Communicated by the Author.

¹ Abbe, *Amer. Meteorological Jour.*, 9, p. 523, 1893.

Anchor Ice.—Barnes² has made a prolonged study of the formation of anchor ice at the bottom of the St. Lawrence River. This kind of ice consists of fine spicules which adhere to the bottom of the river. It is a friable mass which may vary from six to eight feet in thickness. According to Barnes, this ice is formed as a result of the greater emissivity and hence the greater cooling of the material composing the river bottom.

Hoar-frost is another example of ice formation as the result of cooling by radiation. Here, however, the accepted explanation is that the ice spicules are formed by accretion, as the result of the deposition of moisture from the surrounding air.

The foregoing are familiar and interesting illustrations of ice formations on substances as the result primarily of the loss of heat by radiation. We have now to consider a rarer phenomenon, which is the subject of the present paper.

Ice Formations on Plants.—According to the writer's observations, the amount of ice formed upon a plant stem is a function of (1) the rate at which water can rise by capillary action in the sap tubes within the stem, (2) the ease with which the moisture can pass out to the surface, (3) the rate of evaporation from the surface (convection, wind-velocity), and (4) the emissivity of the surface of the stem. Instead of the title "Exudation of Ice," a more pretentious title would have been "The Capillary Movement of Water: An Experimental Demonstration by Means of the Formation of Ice Fringes on Plants." This might appear more scientific and one could discuss the capillary movement of water as a function of the temperature of the stem; the size of bore and number of (sap) tubes; the thickness and permeability of the walls of these tubes, etc. However, the present communication makes no pretence at such completeness of the investigation. In fact, the subject of ice formation forced itself upon the writer at a time when other duties were pressing, and hence it could not be given the attention it deserved. As a result, the experimental tests, to be described presently, were usually carried out only to the extent of refuting the various notions held by various persons as to the cause of this ice formation. All sorts of explanations were presented. This is the main reason for

² "Ice Formation with Special Reference to Anchor Ice and Frazil," H. T. Barnes, *Monthly Weather Review*, May, 1907, p. 225.

giving *in extenso* these simple tests, which show that the formation of fringes of ice on plant stems is not the result of accretion, hydrostatic pressure, rifts in the stem, moisture in the bark, the presence of sap, etc., but that it is the result primarily of the capillary movement of water in the numerous sap tubes which are to be found in those plant stems upon which the ice formations are the most conspicuous.

II. HISTORICAL DATA.

One of the earliest descriptions of the exudation of ice fringes from plants was published by Herschel³ about eighty years ago. His observations relate to the icy fringes which were formed around thistle stalks and stumps of heliotropes, many specimens of which were still green. Stephen Elliott⁴ had previously described a remarkable protrusion of fringes of ice from the stems of fleabane (*Conyza bifrons*).

The fullest account, with an attempted explanation of this phenomenon, was given by John Le Conte⁵ about 63 years ago. His observations are on two species of fleabane, *Pluchea bifrons* and *Pluchea camphorata*, which he found growing in wet soils, around ponds and along roadside ditches in the lowlands of South Carolina and Georgia. In these plants the root is perennial, but the stem is annual and herbaceous.

Le Conte's descriptions differ materially from my own. His observations appeared to establish the following facts in relation to the phenomenon:

1. "The depositions of ice are entirely confined to the immediate neighborhood of the roots of the plants, the upper parts of the tall, unbroken stalks being quite free from them. They frequently commence two or three inches from the ground, and extend from three to four inches along the axis of the stem. The stalks are dead, and quite dry to within about six inches of the earth, below which they are generally green and succulent. The plant has a large and porous pith, which is always saturated with moisture as high as six or seven inches from the base of the

³ Sir John Herschel, *Phil. Mag.* (3), 2, p. 110, 1833.

⁴ Stephen Elliott, "Sketch of the Botany of South Carolina and Georgia," published in 1824, vol. 2, p. 322. Quoted by Le Conte.

⁵ John Le Conte, *Proc. Amer. Assoc. Adv. Sci.*, vol. 3, p. 20, 1850.

stem." From this it would appear that the ice was formed on the green stems, as was true of many of the specimens of heliotrope described by Herschel.

2. "The ice emanates in a kind of riband, or frill-shaped, wavy, friable, semipellucid excrescence, the structure of which (quoting Herschel) is 'fibrous like that of the fibrous variety of gypsum, presenting a glassy, silky, wavy surface; the direction of the fibres being at right angles to the stem or horizontal.'" Le Conte found that the number of ribands varied from one to five, which issued from the stems in vertical or longitudinal lines, often unsymmetrically displaced around the axis. He frequently observed the icy excrescences to exceed five inches in length; often curled back so that the remote extremity of the frill came close to the line of attachment to the stalk.

From this it may be noticed that the amount of ice formed is very considerable. Evidently the moisture must come from within the plant. The amount of water congealed during a single night is vastly too great to come from the aqueous vapor in the atmosphere, hence the phenomenon cannot be a modification of hoar-frost. In fact, in the illustrations to be cited presently, which were observed by the writer, the excrescences of ice on one particular species of plant were formed every night which was sufficiently cool for ice formation, although there was little or no formation of hoar-frost anywhere in the vicinity.

3. Although the ice sheets appeared to protrude from the interior of the stem, both Herschel and Le Conte found that usually the stems were solid and that the ice terminated at the surface. "The point of attachment of the ice was always the wood, beneath the outer bark or epidermis, which the frozen sheets had in every instance stripped off and forced out to a distance." When the frost was severe, Le Conte found that the ice riband was continuous with the frozen pith, through a longitudinal rift in the woody stem.

4. Le Conte found that "the phenomenon took place in the same plant during several consecutive nights; and, when the wood was not rifted, frequently from the same portion of the stalk. When the wood was split, however, the deposition of ice occurred lower down the stem, at a part which was unaffected by the frost of the previous night. The stalks thus become completely rifted by a succession of severe nights, from the height

of six or seven inches down to the ground. This is unquestionably one of the reasons why these exudations of ice are seldom observed after the middle of the winter, for the stalks are usually destroyed before this period."

Le Conte considered the ice formation on plants to be a physical phenomenon, having no connection with the vitality of the stem. His explanation of the ice formation was that the moisture from the pith passes out along the wedge-shaped medullary rays which are to be found in abundance in this plant, and is frozen on the outside of the stem. He considered that the wedge-shaped medullary rays exerted a "projectile force" which brings the moisture to the surface. The exudation of ice columns from the earth he referred to the same cause, viz., a rapid and forcible expansion along capillary tubes.

To the writer it does not appear necessary to postulate a complex "projectile force" to explain the ice fringes on plants. In fact, the plants upon which ice is formed in the greatest abundance have a preponderance of sap tubes, only an insignificant part of the stem being occupied by medullary rays.

Ward⁶ has given a rather popular description of the occurrence of ice fringes. He describes the fringes as projecting out horizontally, "not straight and stiff, but gently and gracefully curving or coiling into a beautiful, conch-like roll at the distal end." His observations were probably of short duration, otherwise he would have found but few instances in which the "fringes are attached at regular intervals around the stem, like paddles of a turbine wheel." He found that the bark was split into strips at the zone occupied by the ice sheets. He concluded that the ice had passed through these rifts in the bark. He thought that the water might have been pressed or drawn up through the cambium layer. He wisely dismisses the explanation because it "explained too much, since no reason can be assigned why the phenomenon should not be universal and not confined to one species."⁷ In the present paper microphotographs of the cross-sections of various plants will assign this reason, viz., the difference in the porosity of the stems.

⁶ Ward, "Frost Freaks of the Dittany," *Botanical Gazette*, 18, p. 183, 1893.

⁷ Ward quotes Gray's Manual, 1848, in which *Helianthemum Canadense* is described as behaving in a similar way.

III. RECENT DATA.

During the past fall and winter (which may be called an "open" one, in that there was no snow until after December 1, 1913) the writer has been walking daily through Rock Creek Park, on his way to and from the Bureau of Standards. The route is along the "Beach Driveway," which winds along the east bank of the creek. This driveway is bordered by a steep hillside, from ten to fifty feet in height, which is thinly covered with second-growth trees, the majority of which are oaks and beeches. There is a thin undergrowth of grasses and of various herbaceous plants with annual stems and perennial roots.

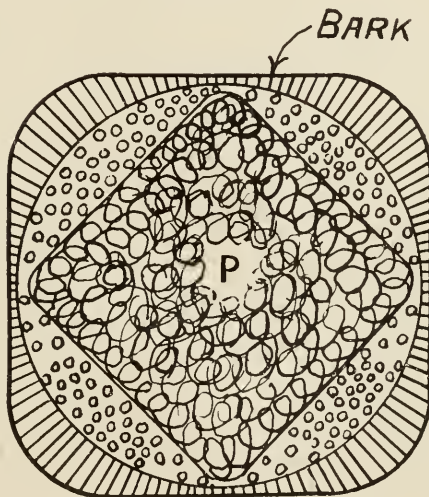
From this it may be seen that the habitat of the plant about to be described is different from the one mentioned by Le Conte, which thrives on wet soils. The present observations are on *Cunila mariana* or Dittany, the stem of which is an herbaceous annual with perennial roots. This plant seems to thrive on dry ground even on bare hillsides, exposed to the blazing sun, where there is nothing but gravel and a few "asters." Other samples were found under trees where either the shade or the gravelly character of the soil prevented a luxuriant growth of other plants. The finest samples were found on a hillside which contained plenty of moisture, which was free from trees, but contained shrubbery.

The first observations were made on a frosty morning in November, 1913. The first example, because of its white, ribbony character, was passed by, thinking it was something thrown from a passing carriage. The conspicuous white fibrous loops and ribbons drew my attention, and it was at once observed that they occurred upon only one species of herbaceous plant. A sample of the plant was sent to Prof. Cleveland Abbe, of the United States Weather Bureau, who pronounced this a rare and an interesting observation, which should be followed up by a more thorough study of the ice formations. While the problem itself seemed a very interesting one in radiation and in the capillary movement of water, it nevertheless seemed an intrusion upon a very busy program of radiation work, so that at first but little attention was given to it, other than scattered observations in passing to and from the Bureau. As time passed, many diverse opinions were received as to the cause of the ice formation. This

called forth additional tests, so that the experimental data now at hand are rather voluminous. In view of the fact that memory is treacherous, notes were taken in the field at the time of observation.

Owing to the pressure of other problems requiring close attention, the tendency at the very first was to dismiss the subject by accepting Le Conte's explanation that the moisture comes from the pith. This explanation was at once disproved, however, by the observations on the splinters of the *Cunila* stem, which formed ice always on the outside of the stem, but never on the pith. This, of course, should be expected, for pith is composed

FIG. 1.



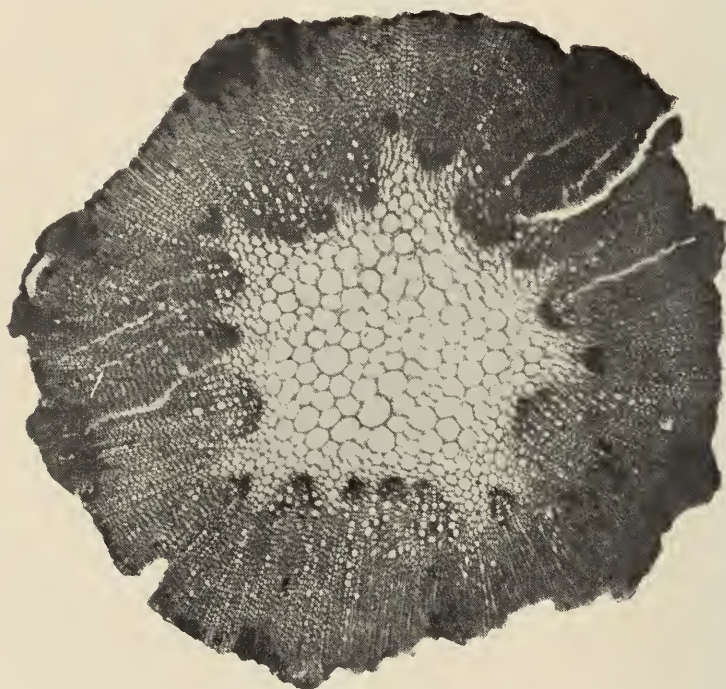
of small hexahedral cells along which water cannot pass by capillary attraction, and it would be very unlikely that it would be transferred by soaking through the cell walls.

Description of the Plant.—The stem of *Cunila mariana* is somewhat angular (especially as viewed with the bark on), having a cross-section of 1.5 to 2.5 mm. The height of the stalk is from 25 to 30 cm. (about 1 foot). The plant stems are very fragile, owing to the structure of the stems, which contain but little wood fibre. The plant is also weak in structure, owing to the great amount of pith and the manner in which the pith is arranged in the stem. As shown in Fig. 1 and Plate 5, the stem is somewhat rectangular in outline, the pith having a similar shape, but the "corners" are rotated 45 degrees. At these "corners" of the pith there is but little wood between the pith and the bark,

and it is along this line that the stem often cracks. Perhaps this is the reason for the persistent belief among the few who are acquainted with the phenomenon that the ice ribbons come from these rifts in the stem. The small stem, weakened by splitting, is an easy prey to the wind.

Photographs were taken of thin sections across the stems of heliotrope, thistle, and also of an aster which was found near a *Cunila* stalk. The object in giving these microphotographs (which were very kindly prepared by Mr. E. D. Tillyer) is

PLATE I.



Aster.

to show a typical example of plants which have but few sap tubes and which form little or no ice fringes; also typical examples of plants which have numerous sap tubes and which form an abundance of ice fringes.

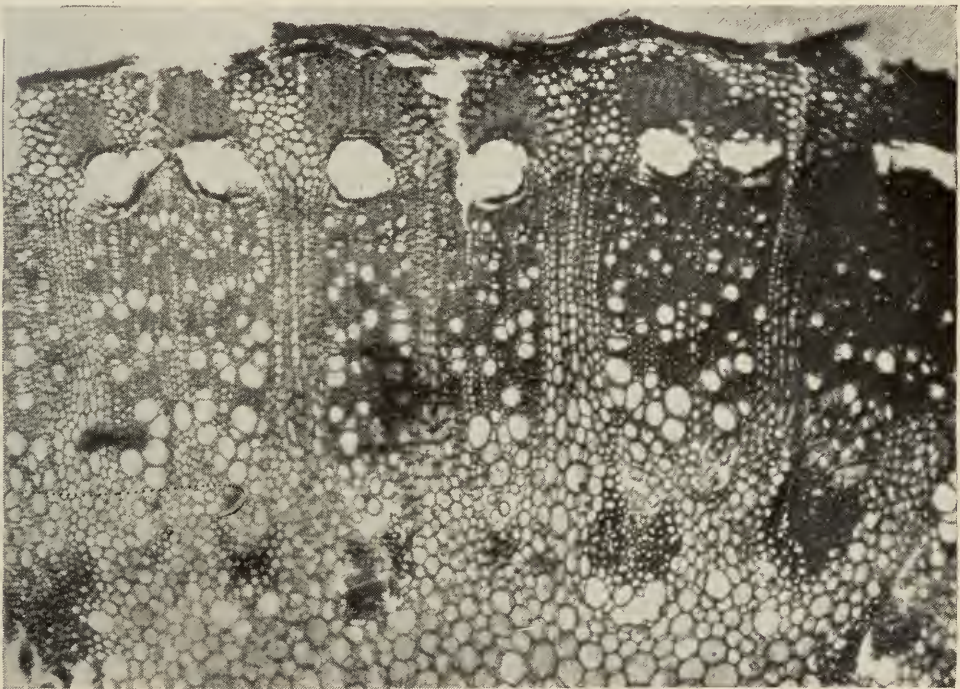
The aster is typical of plants having but few sap tubes. As shown in Plate I, the woody structure is very compact, with but few sap tubes. All these microsections are magnified fifty times, from which one can obtain some idea of the great difference in porosity of the different plants.

On only one occasion was ice observed upon the stem of

the aster. The ice was a small "tooth" formed close to the ground. From the section shown in Plate I it is evident that the structure of the wood fibre is so close that the moisture, which is drawn up within the stem by capillary attraction, can reach the surface of the stem at only a very slow rate. Hence the moisture disappears by evaporation as rapidly as it comes to the surface.

The thistle (Plate 2) and the heliotrope (Plate 3) stems have numerous large sap tubes. In the thistle stem there is a row

PLATE 2.



Thistle.

of large tubes situated near the bark. The presence of these large tubes filled with sap may explain the formation of ice fringes, as observed by Herschel.

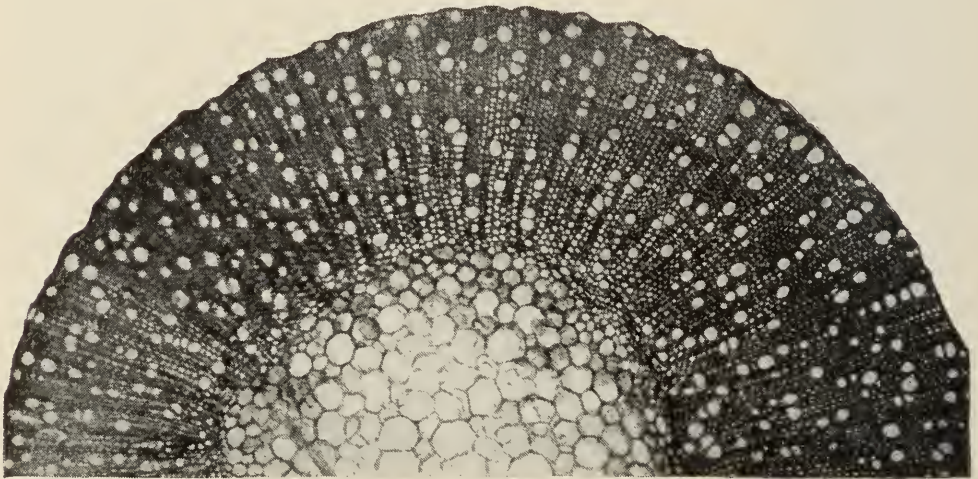
Microphotographs of thin sections of *Cunila* are shown in Plates 4 and 5. The numerous holes in the wood are the "sap tubes," which form an easy path for the moisture to rise within the stem by capillary attraction. It would be interesting to determine to what extent this capillary movement of water is affected by the temperature of the surroundings.

The explanation of the formation of ice fringes, which are

found to occur so abundantly upon the stems of the *Cunila* and which are not found upon other plants, is based upon the presence of a great number of closely adjoining sap tubes within the stem of the *Cunila*. But even the very woody portion of the base of the *Cunila* stem was found to be inactive in the formation of ice fringes.

It was found that the ice fringes rarely start from the side of the stem where the pith is closest to the bark. This eliminates, to some extent, the question whether the pith is instrumental in forming the ice fringes. In the splinters (and in the rifted stems of *Cunila*) at no time was ice found to have formed along the

PLATE 3.



Heliotrope.

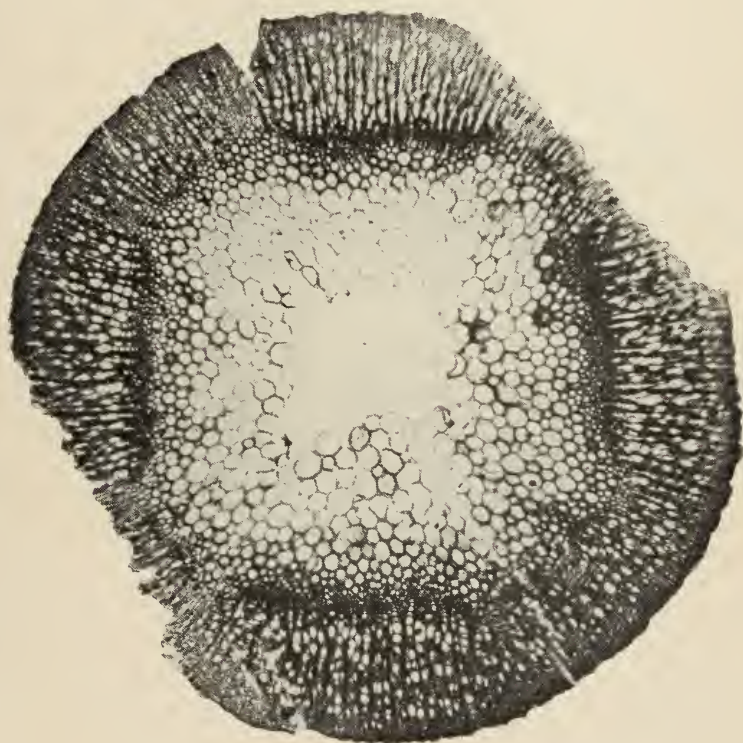
line of separation of the stem. This seemed puzzling at first, for it appeared to contradict the idea that the moisture comes from the sap tubes within the stem; in which case one would expect to find the formation of ice fringes facilitated upon the surface laid bare by splitting.

The microsections of the *Cunila* stems show in a very unexpected manner why no ice fringes are formed upon the rifted surface of the stem. As already stated, the rift always occurs at the "corners" of the pith where the woody part of the stem is the thinnest. In Plates 4 and 5 it may be noticed that at these four points, where the wood is the thinnest, usually there are but few if any sap tubes. Hence one need not expect to find ice formations upon the surfaces formed by splitting.

Field and Laboratory Observations.—The field observations were made on isolated plants found scattered throughout the woods; also on three test-beds of plant-stems, without their roots, which were conveniently located along the roadway.

The first test-bed, Test No. 1, was “planted” January 7, 1914, with plant stems (10 to 15 cm. long) which had been in the laboratory since November, 1913. This test contained (1) a stem and branches with bark intact; (2) a similar stem with two coats of shellac varnish; (3) a stem having the bark thoroughly

PLATE 4.

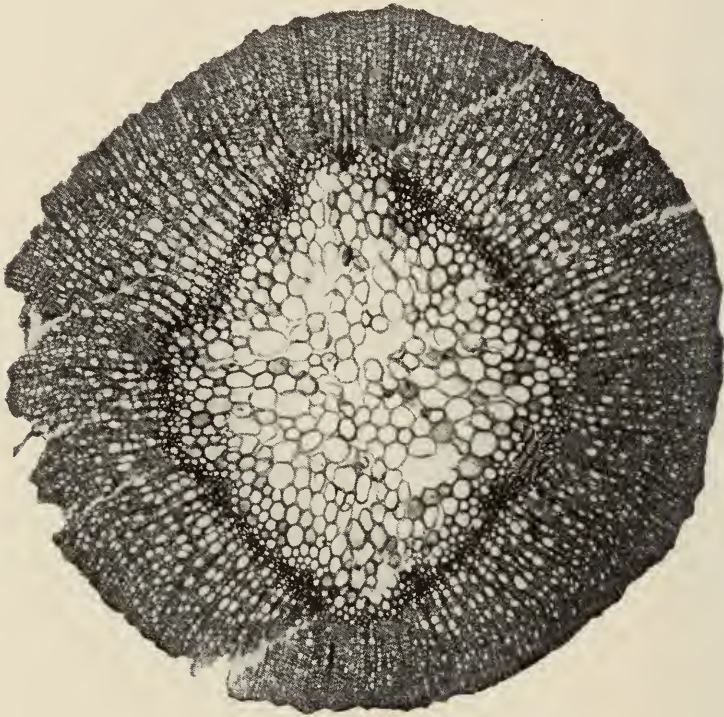
*Cunila mariana.*

scraped from one side, and the other side shellacked over a length of about 8 cm.; (4) a stem scraped on all sides and one-half of it shellacked; (5) a stem having half its circumference scraped, the other half having the bark intact; and (6) a stalk planted head down. The location proved to be a poor one, the ground not retaining moisture. The place was disturbed, but in spite of this some results were obtained.

Tests No 2 and No. 3 were “planted” on January 11, 1914, and consisted of about two dozen plant-tops and stems which

had been broken off by the wind. They were placed on a gravelly bank which was not desiccated by the wind and sun. Some of these stalks were covered with ground up to their branches. In none of the field tests were the tops of the stalks covered to prevent deposition of atmospheric moisture. Test No. 2 contained several stalks of heliotrope (and stems of wild grape vine) which, of course, at this late date were entirely dead. As already mentioned, Herschel found ice fringes on the (green) stumps of

PLATE 5.

*Cunila mariana.*

heliotrope. At no time were there ice fringes formed on the heliotrope (nor on the wild grape stems which were green), especial note of this fact having been made on January 22 and February 2, 1914.

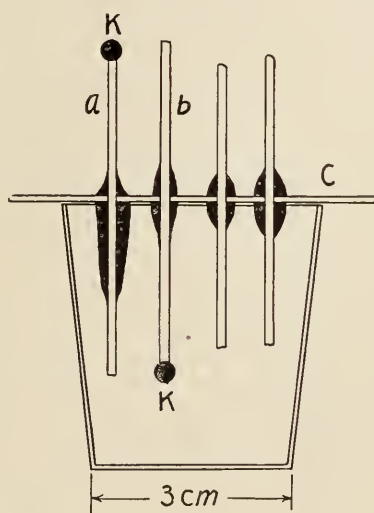
The laboratory tests (started on January 30th) were made on plant-stems placed in a receptacle containing water. In the first and second laboratory tests, "A" and "B," the samples were mounted in a small porcelain crucible, as shown in Fig. 2. The plant-stems were fastened into a piece of heavy cardboard by means of Khotinsky cement. The cardboard was then covered, on

both sides, with paraffin and sealed (with paraffin) to the top of the crucible. A small pin-hole equalized the air pressure, thus preventing any possible hydrostatic pressure. The protruding stems were covered with a glass beaker, which prevented deposition of moisture from the air.

Two additional laboratory tests were made on plant-stems placed in test "C," a test-tube, as shown in the photograph, and "D," a wide-mouthed bottle. In all these laboratory tests the stems were covered to prevent deposition of atmospheric moisture.

Experiments Showing How the Water is Conveyed.—The field observations, "Test No. 1," showed that the water is not transferred along the cambium layer or the bark. Ice was formed

FIG. 2.



on that half of the stem which was scraped, but none was formed upon the part (whether scraped or unscraped) which was covered with shellac. This observation was confirmed on different occasions, especial note of this fact having been made (Test 1, Nos. 3 and 4) on January 8th, 12th, and 27th, and February 2nd and 3rd. In No. 2 of this test the ice forced out the shellac at the juncture of two branches on February 3rd. On these dates (as well as others which would be too tedious to record in this paper) my notes show that ice fringes, large and small, were formed upon numerous plants contained in the plats described as Tests 1, 2, and 3.

The laboratory tests "A" and "B" showed that, starting with stems which had been drying for nine weeks in the labora-

tory, the moisture is transferred very rapidly after placing the stems in water. In Test "A" (see Fig. 2), four scraped samples were thoroughly covered with an impervious cement at the point of contact with the cardboard (C). About 2.5 cm. of the stems extended above the support. The next morning (January 30th) two samples were found thoroughly soaked. They were from the upper part of the plant, hence thin-walled and less "woody." The third sample, which was taken from near the root, was inactive. The fourth showed slight moisture at the top, and by night (24 hours in all) this sample was thoroughly soaked.

The second laboratory test "B" consisted of the two most active samples of Test A thoroughly dried and covered with cement (K), as shown in Fig. 2, and placed in water containing a red dye. The sample, *a*, was covered at the top, K, so that the water would have to come out at the sides. The sides of the immersed part of this stem were covered with cement, so that the water would have to traverse the sap tubes in order to reach the top. The immersed end of sample *b* was covered with cement so that the water would have to soak in through the sides in order to traverse the stem.

The next morning, February 3, 1914, (uncolored) moisture was observed on the sides of *a*, and the top of *b* showed the red dye. Evidently the water had traversed the stems to a height of about 3 cm. by capillary movement. In the subsequent tests, "C" and "D," the stems were more than 6 cm. in length, and it was found that the water rose to a height of 5 cm. However, when uncovered and exposed to the wind the moisture did not rise higher than 1 cm. to 2 cm.

Further Tests Showing That the Water Comes from Within the Stems.—There are several observations which indicate that the water required for the formation of ice fringes comes from within the stem, and that it is not caused by accretion or sublimation, as in hoar-frost. One of the observations applicable to this question was made in connection with the laboratory tests, "C" and "D," discussed elsewhere in this paper. The morning following the formation of the ice fringes on the *Cunila* stems it was observed that considerable water had disappeared from the glass receptacles. The glass beakers covering the stems were perfectly clear, showing that no water vapor had condensed (and frozen) upon them. Evidently the ice fringes had been

formed from the water which had disappeared from the glass receptacles.

Another observation (January 6th) was on a plant (in the woods) surrounded with green moss and well covered with leaves of trees. The stem had several large ice fringes which were hidden by leaves. The leaves were covered with hoar-frost.

A very convincing field test was made by painting the stems with asphaltum in turpentine. If the ice formations were the result of condensation of moisture by rapid cooling, then the black paint should have ice formed upon it. In the afternoon of January 13th (the ice fringes having melted as usual) a number of *Cunila* plants free from bark, situated in various parts of Rock Creek Park, were given a coating of asphaltum paint. "Test No. 2," mentioned elsewhere in this paper, contained several painted stems. As shown in the photographs, the outer edge of the ice fringe is smooth, which could hardly be the case if the formation were similar to that of hoar-frost. On January 27th it was found that ice fringes on two plants in Test No. 2 had pushed out the asphaltum varnish, which was found adhering to the outer edge of the ice, 1.5 to 2 cm. from the stem of the plant.

In Test No. 4 the ice had pushed out the asphaltum and had formed a fringe in the rent in the paint. For some days subsequent to this date there was no freezing weather; but on February 3rd other stalks were found in which the asphaltum varnish was pushed out by, and was situated on the outer edge of, the ice fringe. It may be added that for some days after applying the asphaltum paint the formation of ice fringes seemed to be inhibited.

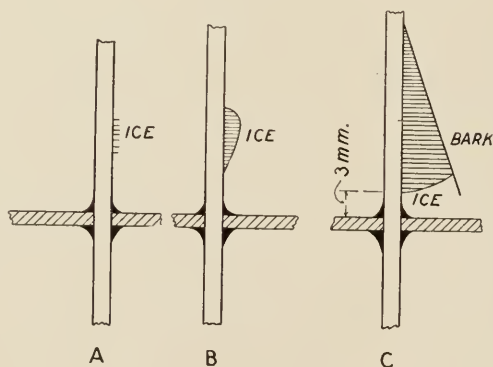
The field tests (Test 1), described elsewhere in this paper, in which one side of the stem was covered with shellac varnish, showed that the moisture was not conveyed from the ground upward along the outside of the stem.

In view of the fact that the bark is often found pushed out by the ice, these tests with asphaltum seem superfluous; but the persistence with which the hoar-frost theory was presented to account for this ice formation seemed to require a *reductio ad absurdum* test. The mere fact that hoar-frost is in fine spicules, while these fringes are smooth, should be sufficient evidence to disprove the hoar-frost theory. If sublimation by cooling had been the cause, then the black paint, with its high emissivity

("cooling power"), should have produced a great amount of hoar-frost upon the outside of the paint. The ice fringes were always formed on nights when the temperature was sufficiently low to cause freezing, whether or not there was hoar-frost in the vicinity.

The actual amount of ice formed (see photographs) is far in excess of what seems possible by the hoar-frost theory. On January 7th the ice fringes formed on a single plant were collected and weighed. The ice formation on this plant, on this date, weighed over 5 grammes. The weight of the ice on the large sample shown in the photograph (Plates 8 to 11) is probably between 4 and 5 grammes.

FIG. 3.



In view of the fact that the stems are dry it is, of course, superfluous to consider the ice fringes to be composed of the "plant juices." The ice is tasteless, in spite of the fact that the plant has a strong fragrance of thymol.

Observations Showing How the Ice Fringe Grows.—One of the most interesting observations was the formation of the ice fringe from its very beginning. This was witnessed by several of my colleagues, who were called in to verify the observations. On a cold morning, February 16th, the samples in Test "B" were placed outside the laboratory window, and in about 20 minutes the ice fringe was observed to be forming. It consisted of a row of fine hairs extending up and down a length of about 4 mm. of the stem, and projecting out horizontally 0.2 to 0.3 mm. (see Fig. 3, A) These filaments were visible only when viewed against sky light, and they melted immediately on lifting the glass cover. The fringe did not appear to form at the line, Fig. 1,

where the pith is closest to the surface of the stem. This experiment was repeated again during the evening. Within half an hour after placing the samples (Test "B" with additional samples) in the cold air one stem showed several fringes in the form of thin, transparent "teeth," each one being about 12 mm. in length and about 1 mm. in height. Another stem showed a fine hairy fringe which was visible when viewed against a gas light. Within half an hour this hairy fringe appeared to be solid, with some of the fine hairs extending horizontally outward through the solid "tooth" of ice, as shown in Fig. 3, B. This, of course, is the general structure of the fringes. By the next morning numerous wide fringes had formed on these stems. In another sample the tooth of ice pushed out a narrow strip of bark similar to the illustration given in Fig. 3, B. In these tests the receptacle containing the water was small, and hence the whole cooled very rapidly and the water froze, which prevented the growth of the ice fringes. It is to be noticed that the ice fringe forms some distance up the stem, at a point where it cools the quickest and where the moisture has risen to about its maximum height.

Test "C," started February 17th, contained half a dozen samples of *Cunila* and a stem of an "aster" in a large test-tube. The test-tube was imbedded in wool to retard cooling and freezing. Within 15 minutes after placing this test outside of the laboratory window two small fringes, 1.5 mm. long and about 0.3 mm. high, were noticed when viewed against the sky light. This test was prolonged for some days and nights, and a photograph was taken (February 18th, Plate 12), showing that the stems, in water, form ice just as they do when attached to the roots. In this photograph, which is magnified slightly (1.2), about one-third of the upper part of the largest fringe is broken off. These fringes appear a little more transparent than usual, owing to melting while taking the photograph.

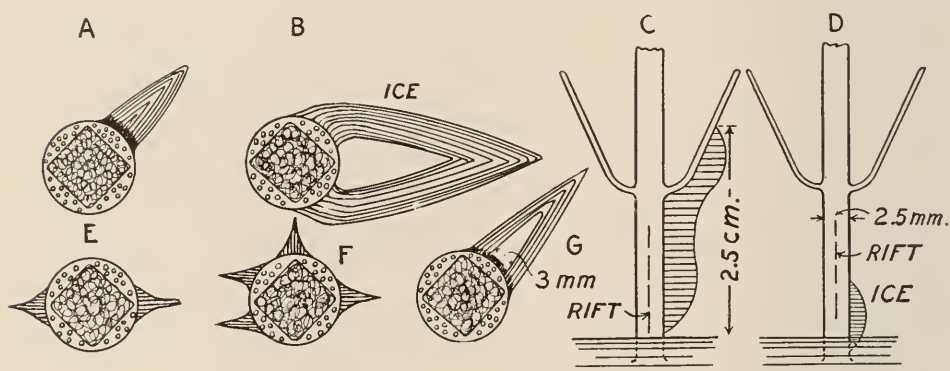
No ice or moisture was formed on the aster stem, which is in agreement with the field observations, where in only one instance was there an ice fringe found upon an aster stem. In this field sample of aster there was but little ice, which was very close to the ground. In Test "C" all the *Cunila* stems showed moisture, and ice was formed on nearly all of them. The thinnest stems formed the most ice.

Test "D," started February 17th, consisted of an assortment

of *Cunila* stems, ten in number, mounted in a large, wide-mouthed bottle, having a capacity of about 1 litre. This bottle was wrapped in hair felt, in a box, which was kept outside the laboratory window. The stems were supported as usual by the cardboard lid, which was thoroughly covered with paraffin. The protruding stems were covered as usual with a large glass beaker, which rested closely upon the felt.

As may be seen from Fig. 1 and Plates 4 and 5, the *Cunila* stem, on drying (shrinking), splits easily into four parts, owing to the small amount of wood fibre at the four sides of the stem. One of the samples used in Test "D" was a splinter, consisting of one-quarter of the stem, about 6 cm. in length, with a line of pith adhering to the inner side. On the following morning, and on subsequent days, this splinter showed a fringe of ice on the

FIG. 4.



woody surface, but at no time was there ice formed on the pith. One sample consisted of one-half of the stem, as shown in Fig. 4, A, and on February 20th a solid fringe or "tooth" of ice was found projecting out to a height of $3\frac{1}{2}$ mm. It was about 2 mm. wide at the base and extended perhaps 1 cm. up and down the stem. An interesting feature (which to the writer became a common observation) was that the ice fringe did not always start at the "corner" of the stem where the wood is the thickest; neither did it start at that part of the stem where the wood is thinnest, but at a mid point, as shown in Fig. 4, A. From the microphotograph of a thin section of the stem it appears that the largest part of the ice fringe may form at the point where the sap tubes lie nearest the surface, hence where the moisture can be supplied the most easily.

Another sample in Test "D" consisted of a thin stem (1.5 mm. cross-section) which was split into four segments for a length of about 2 cm. The ends of the stem were intact. My notes, recorded on the morning of February 20th, state that "one can see through the cracks in the stem. Two ice fringes are formed, extending outward to a height of 7 mm., and extending 12 mm. vertically along the axis of the stem; but they are *not formed in the cracks.*" In fact, the point of attachment of the fringe to the stem, as examined under a reading glass, did not even extend close to the cracks.

In some of the samples in Test "D" the stems were entirely free from bark (see the photographs of Test "C"), while some were covered with bark. In the latter samples the ice pushed out a narrow strip (1 mm. wide) of bark, as shown in Fig. 3, C. This seems to be the usual manner in which the stems are stripped of bark. The bareness of the stem, however, does not seriously affect the ice formation, as may be noticed in the accompanying photographs. One sample had a fringe 3.5 cm. in length and 2 to 3 mm. thick at the base. When the bark is still intact, the ice formation appears to occur most frequently at the "corners" of the stem (see Fig 1). In the bare stems the ice was sometimes found (Test "D," February 17th) to be formed well around the stem, as shown in Fig. 4, B; and numerous field observations showed that this is the result of the fusion of two fringes, leaving a wedge-shaped free space between them. The commonest form, however, is shown in Fig. 4, G (field observations of January 6th and 8th), in which the ice ribbons were described as a composite of thin sheets which were estimated to be 0.3 mm. in thickness. The open space was perhaps 3 mm. wide at the base. The base appeared to be a solid shell 0.5 mm. in thickness. One could easily look through this wedge-shaped opening. Sometimes these fringes adhere well to the stem, so that the ribbon breaks across the open space. After sunrise the stem warms rapidly, which no doubt explains the ease with which the ice ribbon is usually separated from the stem.

The bare stems used in this test were old stalks from which the bark had been separated by previous ice formations in the woods. Evidently the laboratory test did not interfere with the ice formation. The roots are not necessary for the production of the ice fringes. As a matter of fact, the stalk and the nearby

roots are dead, although the rest of the plant (new growth) is perennial.

The ice usually formed on the flat side of the stem, but, as already mentioned, it often was found to cover the whole side, as shown in Fig. 4, *B*. In some stalks the ice "tooth" was found (note of February 17th) to have formed near the "corner" of the stem, as shown in Fig. 4, *A*. Other ice teeth were observed in the process of formation, as shown in Fig. 4, *E* and *F*, the ice being solid, about 3 mm. in length and half a millimetre in height. Fig. 4, *E*, was observed on Test "B," February 13th; and Fig. 4, *F*, was found in the field on January 11, 1914. In view of the fact that the general notion is that the stems are split by the frost, it is important to notice that in these laboratory tests none of the stems were rifted by the ice formation. The rifted stems used in these tests were samples which had cracked on drying and shrinking, after having been in the laboratory.

The ease with which these stems became saturated with water after having been drying for weeks is another item worth noticing. All the stems used in Tests "C" and "D" had been in the laboratory for some time. Some of them had been gathered in November, 1913, and had been freed of bark by previous ice formations.

It is generally supposed that the ice is formed more easily in the fall (when the plants are fresh) than in the late winter. This seems to be true, to some extent, according to my field observations and to my laboratory tests. In the latter, Tests "A" and "B," the ice did not seem to form so abundantly after the stems had soaked for some weeks. It seemed as though the sap tubes became clogged, or the plant had begun to decay.

Although the laboratory tests were continued after February 21st, no records were kept, and at the risk of being prolix the notes of the last two mornings are given herewith.

On February 20th (warm and rainy the first part of the night, cold and freezing in the morning) moisture and ice fringes were found extending 2.5 to 3 cm. up the stems. Test "C" contained 5 *Cunila* stems and one "aster" stem. Ice fringes were found on four of the five *Cunila* stems, but no ice or moisture was found on the aster stem. There were two to four fringes on each stem, some of the fringes being 1 cm. wide,—*i.e.*, extending outward horizontally 1 cm. from the stem. The last laboratory observations were made on the morning of February 21, 1914. Tests

"B," "C," and "D" were under observation, having, of course, been started the previous evening. Test "D" had ice fringes on seven of the nine stems of *Cunila*. The thick *Cunila* stumps did not seem to be able to form ice, and there was no moisture on them. Test "C" had ice fringes on all the *Cunila* stems (there were four stems), but no ice or moisture was on the aster stem. The aster is one of the common plants found growing near some *Cunila* stalks, but was so badly broken that it was not identifiable with any of the numerous asters which abound in the locality. Some stems had four fringes, but no ice was observed in the cracks which were in one of the stems. Some of the fringes were curled back against the stem.

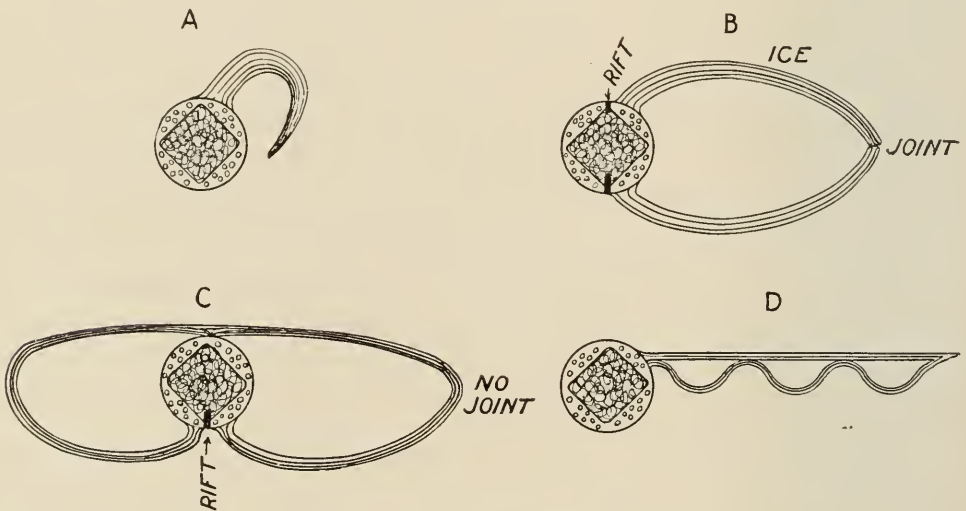
Test "B" showed ice fringes on two of the three stems under observation. The third stem was a very thick one, which showed a fine line of ice just starting. The fringes were small, being only about 3 mm. long and 2 to 3 mm. high.

The peculiarity of the fringes, on February 21st, was that in all three tests ("B," "C," and "D") the fringes were small, and the outer edges were curved back against the stem, as shown in Fig. 5, *A*. This seems an interesting observation, for it serves to explain the peculiar ice loops one so frequently observes in the field. They no doubt start as a thin fringe (as in the laboratory test of February 21st), one side of which grows faster than the other, thus forming a curved fringe, as shown in Fig. 5, *A*, which in some cases seems to freeze against the stem. As more ice is formed the loop is merely enlarged, as shown in Fig. 5, *B*, which is a field observation (January 18, 1914) on a rifted stem where no ice was formed in the rifts. This loop was jointed at the ends. A still more remarkable formation (observed January 18, 1914) is shown in Fig. 5, *C*, which also showed no ice formed in the rift. In this sample it was especially noted that the loop was not jointed. A further illustration of the composite character of the fringe is shown in Fig. 5, *D* (field observation January 18th), in which one side of the fringe has intermittently grown faster than the other side, thus forming a wavy, fluted surface, while the other side is smooth. My notes of January 18th state that the loop is usually jointed at the outer edge (Fig. 5, *B*), the fringe usually starting near the rift.

These illustrations seem to indicate that the ice fringe has its beginning in a row or several rows of fine, hair-like filaments of

ice, as shown in Fig. 3, *A*. These filaments of ice, which remind one of the finest filaments of mold, increase in number, thus filling in the gaps, and form a continuous film of ice. They extend upward and downward along the axis of the stem; and they widen out, thus producing the sharp, wedge-shaped formation of ice which one finds in the early stages of growth of ice fringes. It is possible that when the plant is exposed in the open fields the fine, hair-like filaments of ice, which constitute the first stage of the fringe, are not formed, and that the thin, solid, tooth-like formation constitutes the beginning of the ice fringe. As shown by the laboratory test, however (Test "B" mentioned on a previous page), the ice fringe passed through both stages of growth. At

FIG. 5.



7 P.M., February 16th, the fine, hair-like filaments were visible. At 7.30 P.M. these filaments had multiplied and coalesced into a solid film, with hairy streaks in it, as illustrated in Fig. 3, *B*. The following morning the fringe had grown larger than the sample shown in the photograph (Plate 12) of Test "C."

These laboratory tests serve to explain the filamentous structure of the mature ice fringes, which are always found to be fibrous, the ice ribbon often breaking into several ribbons. This is well illustrated in the large ice fringe shown in the photograph (Plate 7) of Test "C." The light, horizontal lines show the edges of the individual fringes. In fact, this particular sample contained large, open spaces, in spite of the fact that it was not more than 2 mm. in thickness,—*i.e.*, the thickness of the stem.

The formation of the ice filaments (Fig. 3, *A*) might be used as evidence in supporting Le Conte's theory of a "projectile force" which produces the fringe. The difficulty then arises in attempting to find the cause of the projectile force. The physical forces now familiar to us seem sufficient to account for the phenomenon, without invoking unknown forces. These known physical activities are: (1) cooling of radiation, (2) a rapid capillary movement of water through the interior of the plant, and (3) sufficient moisture in the soil so that the capillary forces can bring moisture to the surface at a greater rate than that at which moisture passes into the air by convection and by evaporation. The capillary movement of water may possibly be accelerated by the temperature gradient in the stem, which is cooler on the outside.

The main difficulty in this explanation of the cause of ice fringes lies in the fact that the second stage in their formation is an apparently solid wedge of ice (see, however, Fig. 3, *B*), whereas the mature fringe is fibrous in structure, is very friable, and often separates into a series of thin, wide ribbons, as thin as tissue paper. This fibrous structure, however, may be the result of re-formation by variations in air temperature, by evaporation, etc., which produces the white fringe shown in the photographs. The laboratory formations never appeared quite so white. The great transparency of the sample, Test "C," shown in the photograph, Plate 12, is owing to melting while taking the photograph. The field specimens differ greatly in translucency. On a cold, frosty, cloudy morning (January 18th?), the atmosphere having a "damp" feeling, the numerous ice ribbons, 2 to 3 cm. in length, were conspicuous for their great transparency.

What Determines the Location of the Ice Fringe upon the Stem?—The ice fringe is usually found to adhere loosely to the stem. It seemed to continue to increase in size even when the ground surrounding the plant was frozen to a depth of 1 to 2 cm. As was found by Le Conte, the ice formation ceases its growth after the ground has become frozen to a considerable depth. The moisture in the stem is then found to be frozen, and ice is found in the (rifted) stems. On very cold mornings the ice fringe extended down to the ground (observation of January 11th). The closeness with which the fringe approaches the base of the stem depends, of course, upon the temperature of the ground.

The height to which the fringe can form seems to be governed by the rate of capillary movement of the water, and the rate of evaporation (and convection) from the surface. In the laboratory tests where the plants were covered and protected from the wind the moisture rose 5 to 6 cm. in the stem; but on removing the cover evaporation reduced this height to 1 to 2 cm. When the soil was wet the ice ribbons were the widest. For example, on January 7th a width of about 4 cm. ($1\frac{1}{2}$ inches) was recorded. After several days of cold and freezing, the ground having become quite dry, the ice fringe was short and did not rise more than 1.5 cm. above the ground. There is evidence that the ice fringe may form on a definite position of the stem. For example, one stem which on February 17th formed a large fringe on the "outside" (see photograph Test "C"), *i.e.*, near to the glass cover, was rotated 180 degrees. The next morning the ice fringe was found to have formed on the "inside," *i.e.*, on the same side of the stem, showing that proximity to the glass cover did not change the location of the fringe upon the stem.

The location and the amount of the ice formation are evidently determined by the ease with which the moisture can be supplied from within the plant. An examination of the cross-sections of plant stems showed that sap-tubes may be located very close to the outer wall of the stem. One would expect this to be the starting point and the most prolific source of production of the largest fringes. In the laboratory test-sample, the stem showing this property was one from which the bark had been scraped, and the abrasion may have been deeper on the side which produced the most ice.

In the field one strong, weather-beaten plant (stem without bark, 2.5 mm. in diameter), situated on a steep bank, was observed, all winter long, to form the ice fringe on one side. It was split as shown by the dotted lines in Fig. 4, C, but no ice was observed in the rift. Sometimes the base of the ice tooth was almost solid and embraced half of the stem, as shown in Fig. 4, B. After a rain, when the ground was quite wet, the ice fringe extended 2 to 2.5 cm. up the stem and out along a branch (observation of January 11th), as shown in Fig. 4, C. On other mornings when the ground was dry and powdery there was but little ice formed above the loose earth, which continued sliding down the steep, bare hillside. The ice fringe, however, whether a wide

ribbon or a short, wedge-shaped tooth, Fig. 4, *D*, half buried in the shifting dry ground, was always formed on the same side of the stem. The clump of (three or four) plants of which this was one stem never formed such long ribbons as was to be observed on other stems which were situated on a lower level on this same bank, where the ground was always moist. The plants of Test 2, described elsewhere, were located on the lower level of this steep hill, also stumps of *Cunila* from which the tops had been cut. No ice was observed to form on the cross-section of the stump; but long, curled ribbons of ice continued to form along the side of the stem which was on a level with the ground. The soil itself

PLATE 6.



formed excellent samples of "ground ice." It was, therefore, an interesting sight to sometimes observe the ice fringes from the stumps of *Cunila* protruding out over the ground ice. The ground ice formed only after rain when the ground was wet, *i.e.*, contained a certain amount of moisture.

Description of Photographs of Ice Fringes.—The attempts at photographing the ice fringes as they occurred in the woods were far from satisfactory. This was owing to the fact that at 8 A.M. the illumination was low. A wide stop was used in the camera, and consequently the objects are in focus only in the centre of the photograph. They serve the purpose, however, to illustrate their general appearance as found in the woods. The ice fringes are viewed at an angle of almost 45 degrees. However, a general idea of the size of the fringes may be obtained

by comparing them with the accompanying pocket-knife, which is about 14 cm. in length.

The photograph, Plate 6, was obtained on January 7, 1914. It is typical of what one finds as regards size and general appearance of the ice fringes. The fringe in the lower left-hand corner

PLATE 7.



is composed of three whorls; the open space in the fringe nearest the knife is shown by the round dark spot in the centre. The brightest ice fringe in the stalk in the centre of the picture is not unlike the large sample shown in Plates 8 and 9. This photograph

PLATE 8.



shows seven stalks with ice fringes. One formation in the lower right-hand corner of the photograph is broken. The *Cunila* stalk upon which this fringe was formed (the stalk with the three branches) shows the bark pushed out at the base of the stem, with some ice still adhering to it.

Plate 7 was obtained in the middle of January. The ice formation in the centre of the photograph contains four beautifully folded fringes, the markings of which are, unfortunately, lost in the print.

PLATE 9.



The finest photographs (Plates 8, 9, 10, and 11) were obtained by collecting a number of ice fringes one cold, frosty morning (January 6, 1914) and having them photographed at the Bureau of Standards. Grateful acknowledgment is due Mr. E. D. Tillyer

PLATE 10.



for his painstaking care in making these photographs, which no doubt are the finest records yet obtained of these beautiful ice formations.

In Plate 8 the four most conspicuous ice fringes are lettered *a*, *b*, *c*, *d*, which makes identification easy in Plates 9, 10, and 11.

In these plates the ice fringes were photographed from different sides. In Plate 8, *a*, it may be noticed that the stem is free from bark.

In Plate 9, *a*, an extremely thin, delicate fringe may be noticed protruding from what appears to be a rift in the stem, but what in reality is a piece of bark. It is an excellent illustration of the second stage in the formation of the ice fringe as described on a preceding page and illustrated in Fig. 3, *B*. Plates 10, *a*, and 11, *a*, give further views of this ice formation, which consists

PLATE II.

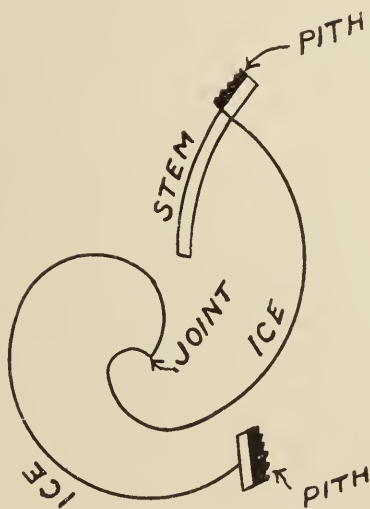


of two large fringes, twisted and whorled. In Plate 10, *a*, the oft-mentioned thin, wedge-shaped fringe (see Fig. 4, *E* and *F*) is shown to advantage, protruding (upwards in the photograph) from above the large fringes. The *Cunila* stalk *a*, shown in these plates, is typical of what one finds after several ice formations, when the stem is well stripped of bark. The stem is 2.2 mm. in diameter and it is not rifted. As shown in Plate 10, *a*, the "width" of the fringe adhering to the stem is 3 cm. It extends out horizontally 3 cm. from the stem. The distance from the stem to the extreme distal end of the loop is 4 cm.

Plate 8, *b*, consists of three splinters, united at the base of the

stem. They are, of course, the remnants of the stalk, which had long since disappeared. The dark line in the wood is the pith, which is shown to better advantage in Plate 11, *b*, and Fig. 6. Plates 9 and 10 show the pith side of another splinter. We thus have a photographic record of the ice formation, not only upon the unrifted stalk, but also of the formation of the rifted stalk (Plates 8, 9, 10, and 11, *c*) and of the formation upon the bare splinters. This is an unusually interesting ice formation. The peculiar whorl in the centre (Plates 9 and 10, *b*, are top views) is the meeting-point of two fringes (see Fig. 6), both of which began curving clockwise. The extreme thinness and the great transparency are to be noticed (see also Plate 3, *d*) by the light and the dark streaks through the fringes.

FIG. 6.



The small ice fringes on the stalk shown in Plates 8, 9, 10, and 11, *c*, are of interest because they occur upon a thin stem which is split into two parts, the rift being easily distinguished in the photographs. In fact, most of the rift is above the ice fringes. This ice formation is also conspicuous in having pushed out some of the bark, as illustrated in Fig. 8, *c*. This is an excellent photographic record showing that the ice is not formed upon the pith (Fig. 8, *b*) or in the rift of the *Cunila* stem.

Plates 8, 9, 10, and 11, *d*, give a further illustration of the formation of ice fringes upon fragments of stems of the *Cunila*. The sample is a very small one. The stump of the stalk had to be

cut out of the ground in order to obtain the fringes. Some of the ground is still adhering to the stem. One of the fringes is broken off. The extremely thin, translucent fringe (it appears to be dark, owing to the dark background) on the right-hand side of Plates 8 and 11, *d*, is an excellent photographic record of the manner of growth of the ice fringe, as described on a previous

PLATE 12.

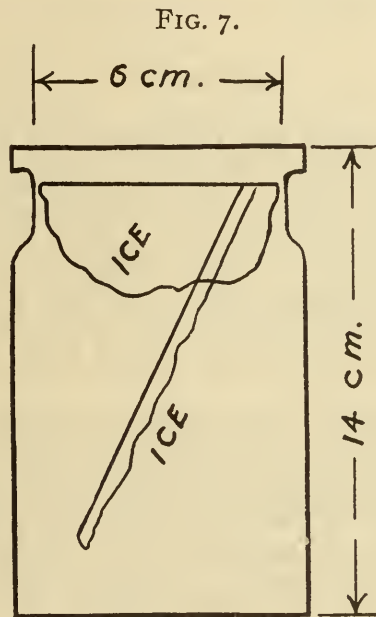


page. The growth of the fringe is along a straight edge, which appears almost horizontal in the photograph. This, however, is partly owing to the peculiar curvature of the fringe. The distal edge is straight and smooth, just as it started when near the stem. The photographic record is, therefore, an excellent contradiction of the hoar-frost theory of accumulation. In the tests with the asphaltum already described the ice fringe had a similarly

formed straight edge. The dark streak along the fragment of stem is pith. The ice fringe is upon the woody side of the stem.

Plate 11 shows the upper parts of the stem, a few leaves and the showy seed capsules. All the plates show fragments of ice fringes, the bright and dark streaks of which are owing to the difference in thickness and hence in transparency of the ice.

Plate 12 is a photographic record of the laboratory Test "C." It was taken by the writer February 18, 1914. The test-tube was about 20 mm. in diameter, which gives one some idea of the dimensions. The test is described on a preceding page. This



record is of interest mainly in showing that the *Cunila* stems, after having been in the laboratory for some months, form ice fringes, just as they do when attached to the roots.

Ice Formation in a Large Body of Water.—In view of the possibility that the ice formed at the bottom of a river (the Anchor ice mentioned at the beginning of this paper) may be owing, in part, to some other cause in addition to the high emissivity of the river bottom, it is desirable to call attention to a peculiar formation of ice as the result of cooling and refrigeration in a body of still water.

In Test "D," already described, the receptacle containing the water was a wide-mouthed bottle, 6 cm. in diameter at the top and about 14 cm. in height. The bottle was wrapped in hair felt and

tightly packed in a box. Cooling was therefore mainly by conduction and radiation from the top. On one occasion it was observed that instead of the ice freezing solid across the top, there were several extremely thin "curtains" of ice suspended in the water, as shown in Fig. 7. They were visible only in intense sunlight. Several thin, narrow, saw-toothed blades extended far down inside the bottle. They seemed to take the line along which refrigeration occurred, as a result of cooling, principally by conduction and radiation at the top of the vessel. It would be desirable to determine whether the density of these fine ice spicules is the same as that of a large mass of ice.

SUMMARY.

This paper deals with the formation of ice fringes upon the Dittany (*Cunila mariana*). The data presented are based upon experiments and observations in the field and in the laboratory.

It was observed that the ice fringes are formed when the temperature falls to freezing point (0° C., 32° F.); but they are not a function of the hoar-frost which may be present upon the ground.

The ice fringes do not form upon the side of a splinter which contains the pith or upon the line of fracture, but upon the outer woody surface. The formation of the ice fringe, however, is not a function of the surface condition of the stem. The stem is frequently found to be cracked, but usually no ice protrudes from the rifts.

The growth of the ice fringe ceases when the ground is frozen to a depth of 2 to 3 cm., and when the moisture in the stem is frozen.

The size of the ice fringes and the height to which they extend above the ground depend upon the rate of evaporation from the stem and upon the amount of moisture in the ground. Over 5 grammes of ice may be formed upon a single plant during a single night.

Photographs are given of ice fringes formed upon stems which had been kept in the laboratory several months. They show that the ice may be formed upon stems without the roots. Hence the ice is not formed as a result of hydrostatic pressure exerted by the roots, which are perennial.

All the observations are in agreement in showing that the moisture arises in the stem as the result of capillary attraction. The height (1 to 5 cm.) to which the moisture can rise within the stem is governed partly by the rate of evaporation from the surface.

Microphotographs of thin sections of plants are given, which show the structure of stems of plants which do not form ice fringes; also microphotographs of sections of stems of plants which form ice fringes. It is shown that those plants which form ice fringes the most readily and in the greatest abundance have the most sap-tubes.

The ice fringe is a composite of a number of very thin ribbons. In the laboratory the formation of the ice fringe was observed from its very beginning. The first stage in the production of the ice fringe consists of a single row of fine, hair-like filaments of ice. This row of ice filaments lengthens, up and down the stem. The filaments increase in number, thus forming a solid wedge-shaped tooth of ice, which constitutes the second stage of development. In the third stage of development the wedge-shaped tooth of ice widens and increases in length, as the result of freezing of the water which continues to soak out of the stem.

There appears to be no difference between the formation of these ice fringes and the "ground ice" formed on wet soils, other than that in the latter a particle of gravel usually forms the nucleus to start the congelation. In both cases the moisture is brought to the surface by capillary action. When the rate of supply to the surface is more rapid than the loss by evaporation, and the air is at a sufficiently low temperature, ice is formed.

WASHINGTON, D. C., June 25, 1914.

Phase Compensation. G. H. EARDLEY-WILMOT. (*Electrician*, lxxiii, 51.)—The different kinds of plant available for phase compensation are considered, such plant being classed as (1) that which may improve the power factor of the system as a whole, and (2) that which is applied to individual motors. The overexcited synchronous motor is first considered, the effects being illustrated graphically and by specific instance. Reference is then made to condensers, and, lastly, a case is taken where a rotary phase advancer is used. It is pointed out that the type of plant to be adopted must depend on the circumstances of each case, as it is impossible to lay down any general rule.

Paper Standards and Paper Testing. C. F. CROSS. (*Papier fabrik.*, xii, 831.)—The primary physical properties involved in paper testing are: In breaking strain, the sectional area; in specific volume-weight, the density or concentration of fibre substances. In testing for strength, the breaking strain should be referred not only to the unit of sectional area of the strip, but the results should also be calculated on the assumption that the area broken consists entirely of fibre substance without air space. The ratio of thickness of paper to absolute fibre density should always be kept in view. The suggestion by Briggs that breaking strain and volume, both referred to unit weight of paper substance, should be combined additively to give an expression for "handle" is criticised, the author's view being that any combination of the two factors mentioned above should be expressed as a product.

Wood-preserving Industry in the United States, 1913. (*Board of Trade J.*, July 20, 1914.)—Returns from 93 wood-preserving plants, of which 58 are commercial plants and 35 private plants, 26 of which are operated by railway companies, show that in 1913 these plants treated 153,613,888 cubic feet of material, or 21.9 per cent. more than in 1912. The total consumption of creosote oil by these plants in 1913 was 108,873,359 gallons, an increase of 29.5 per cent. over the previous year; the consumption of zinc chloride amounted to 26,466,803 pounds, an increase of 27.5 per cent., and of miscellaneous liquid preservatives 3,885,738 gallons, an increase of 26.4 per cent. The quantity of creosote imported in 1913 was 62 per cent. of the total amount used. Plants for the manufacture of creosote oil are now being erected in the middle West, and, if present plans materialize, should add about 10,000,000 gallons annually to the available supply of creosote.

Tellurium as a Coloring Agent in Soda-lime Silicate Glass. P. FENAROLI. (*Chem. Zeit.*, xxxviii, 873.)—Tellurium, like sulphur and selenium, acts as a coloring agent in glass only under reducing conditions, in which case it may be present as a colloidal solution of the element, causing blue or brown colorations, or as a polytelluride which yields a red glass. In the blue glasses the colloidal particles are larger than in the brown. The absorption spectrum of the red glasses corresponds to that of aqueous solutions of polytellurides with a characteristic maximum between 480 and 490 μ . Comparing the members of the sulphur family, it is concluded that in combination with an alkali metal their staining power tends from yellow to red with increasing atomic weight; that they form colloidal solutions in glass more easily as the metallic character of the element increases, the analogy between selenium and tellurium being greater in this than between sulphur and either of them; and that none of them colors glass under oxidizing conditions.

PROGRESS IN INDUSTRIAL FELLOWSHIPS.*

BY

RAYMOND F. BACON, Ph.D.,

Director of Mellon Institute of Industrial Research and School of Specific Industries of
University of Pittsburgh.

RELATIVE to the paper by Dr. Duncan on "Industrial Fellowships," which appeared in the JOURNAL OF THE FRANKLIN INSTITUTE in January, 1913, it is gratifying to be able to state that the system therein presented has since received a splendid recognition in the gift of over half a million dollars on the part of Messrs. Andrew W. and Richard B. Mellon, bankers and citizens of Pittsburgh, for its permanent establishment under the name of the "Mellon Institute of Industrial Research and School of Specific Industries of the University of Pittsburgh." Of the sum thus presented, \$250,000 is being used for the construction of a beautiful, permanent building on the campus of the University; \$60,000 was made immediately available for the purchase of permanent equipment in the form of apparatus and supplies, \$20,000 for the purchase of the nucleus of a chemical library, and \$40,000 a year for at least five years for maintenance.

The Mellon Institute thus established is an integral part of the University, with the exception that it has a special Board of Trustees, in the membership of which the University is represented, and that under this Board of Trustees it manages and controls its own funds and affairs; in all instructional matters it is in the closest relationship with the University.

The building, when completed, will afford ample accommodation for seventy researchers, it being thought advisable to limit the researchers to this number owing to the necessity, on the part of the administration, of keeping in the closest personal touch with the work of the individual researchers and the advisability of conserving the fraternal spirit of the organization. The building is being constructed so as to afford every possible facility conducive to a successful outcome of the researches concerned. The sum of \$60,000 provided for the purchase of initial apparatus and supplies will insure, as well, the means for every researcher

* Communicated by the Author.

to go from what may be called the "test-tube" scale of experimentation to a scale sufficiently large to justify the industrial installation of a process.

In addition to the researchers thus provided for, the building of the Institute will afford ample accommodation for a Graduate School of Specific Industries; and, as this is altogether a new idea in education, I beg to explain it.

As the Industrial Fellowships which constitute the basis of this system are constantly increasing in amounts subscribed by the industrialists for their maintenance, and, as well, in their importance, it is, of course, obvious that the seventy researchers thus provided for will number among them men of national or international importance, to say nothing of the fact that as a class they are carefully chosen as picked men from the best institutions of learning and from the greatest industrial organizations in this country. Such a corps of workers will, therefore, be of the highest potential value as an educational staff for students fitted to receive such instruction. Enthusiastic young chemists who have received a thorough training in the fundamentals of the science and who desire to make their life-work in a certain industry may thus become thoroughly familiar with the application of chemistry to that particular industry—by being in intimate contact with those who are devoting their whole time to the problems of that specific industry. Thus, for example, the man who wishes to become an expert in *glass* will work in the laboratory and in the glass factory with those who have for a long time been devoting themselves to the problems of the glass industry and who are in the forefront of that industry.

The young man just out of school, going directly into the factory, is apt to encounter many conditions so discouraging¹ that unless he is of very exceptional calibre and unless he receives more than ordinary encouragement from those in charge of the business he may lose his enthusiasm and degenerate into a routine man and, perhaps, never be able to contribute anything to the up-building of that particular industry. American factories, as a rule, do not have adequate laboratory facilities for research, and too many American business executives do not appreciate the time and difficulties involved in prosecuting successful research. Many lines of business are so full of tradition and prejudice that

¹ Duncan, Robert Kennedy, Jr. *Ind. and Eng. Chem.*, vol. iii, 1911, p. 177.

serious obstacles are often deliberately put in the way of the young chemist by misguided workmen and superintendents to prevent his experiments from turning out successfully. Another point of considerable importance in this matter has to do with the organization of many American factories. While the higher executives of the company may thoroughly appreciate difficulties of research and the time often necessary for its successful prosecution, in the actual factory organization the chemist is very often placed immediately under and must report to some man who does not have such breadth of view. This man is often the factory superintendent, who may be chosen primarily because of his ability as a driver of men. The factory superintendent may tell the chemist to undertake a certain piece of research. In a few weeks—or sometimes even in a few days—he comes around to find out the result obtained. If no result is available, very often the chemist is shifted to other problems; or it may be that something unusual, which has just arisen, seems of pressing importance and the chemist is asked to drop everything else to take up the new matter. The net result is that after a few attempts by the young chemist to do big things, unsuccessful because the necessary uninterrupted time was not allowed, the factory superintendent reaches a conclusion that nothing can be gained by the research of the chemist and the chemist himself, if young and inexperienced, may lose his ideals² of research.

Under Dr. Duncan's system of Industrial Fellowships, the Mellon Institute and its Fellow have the sympathy and hearty coöperation of the higher officials of the corporation concerned; and yet in his work the Fellow is to a considerable extent independent of that corporation, as he is under the immediate control of the administration of the Institute. The Institute is thus able in many cases to push through to a successful conclusion large-scale experiments in the factories of the corporation which could hardly be accomplished by the company's own chemists. The young student entering the School of Specific Industries learns the difficulties which must be overcome in successful large-scale work, not only on the purely scientific and experimental side but also on the human side, and finds that by proper and tactful methods these human difficulties can be met; so that instead of

² Robert Kennedy Duncan, *Harper's Magazine*, February, 1913, vol. 126, pp. 385-90.

losing his first rush of enthusiasm he gains by actually seeing ideas and theories grow into commercial realities.

Such, in brief, is the idea of the School of Specific Industries. It is not the intention to go out after students for this school, nor is it the intention ever to have very many students in the school, but it is believed that the proper sort of young men will seek its instruction.

By the time that this article appears in print it is probable that the Mellon Institute will be operating in its new building. On its door is the following inscription, which expresses in a few words the ideal for which it is striving:

"This building is dedicated to the service of American Industry and to young men who destine their life-work to the Industries; the goal being Ideal Industry, which will give to all broader opportunities for purposeful lives."

In its equipment the Institute is somewhat different from the usual scientific laboratory. As a new process is but barely started towards commercial reality when it has passed the test-tube stage, the Institute has been very well equipped with unit apparatus for conducting chemical operations on a large scale; and in a broad sense the equipment of the Institute may be said to include the factories of the corporations which are using its facilities. The usual history of a new process as worked out in the Institute is somewhat as follows. The researcher conceives and works out this process at first with the usual apparatus of the scientific laboratory and by the same methods which are used in research in pure science, all the conditions affecting the reaction involved being determined with even more care and accuracy than is often necessary in a purely scientific investigation. The next stage is to perform the same reactions, still on a very small scale, but in apparatus which is constructed of materials which are available for larger scale work. To this end the Institute is well equipped with the usual standard large-scale apparatus for heating, distilling, drying, etc., and has, in addition, an excellent workshop with several trained mechanics who build special small plants. After the difficulties of materials and of construction are solved, the next stage is either one of two things: (1) The equipment of the company's factory may be such as to permit a trial of the new process directly in the factory—and it has been found that American manufacturers are very willing to have such trials made when

the previous work has been of such a character as to indicate a reasonable chance of success; (2) or, in case the process demands apparatus of a new type, which is not available in the factory, a unit plant is built. This plant is of such a size and is built in such a way that when it is running smoothly the manufacturer will feel justified in taking over its plan and spending such money as will be necessary to put in a very much larger unit or, it may be, several units. I might say that the companies which are using the Institute have, during the past year, spent approximately \$55,000 in building small unit plants to develop the processes which have been worked out in the laboratory. This does not include many processes which were adapted to the factory equipment already on hand. In no case was any of this money for plants provided for in the original foundation of the Fellowship, but in every case after conference the company felt that the progress of the work and the results obtained appeared promising enough to justify them in the expenditure of this money for further development. In the case of a number of these small plants in which processes have been developed, and where the processes have now gone into the commercial scale of operation, the plants are still available, being located in small, temporary buildings around the Institute; and such unit plants can often be adapted to the study of other new processes. The Institute is thus gradually acquiring what might be called a "large-scale equipment" that is undoubtedly unique in American laboratories. It might be well in this connection to say a few words as to just how the Fellowships which have been operating under this system are turning out. In a recent conversation with one of the foremost American technical chemists, who has built up more than one great industry on the basis of research done under his direction, this chemist expressed the idea that while he was firmly convinced of the practical dollar-and-cents value of research and he felt that a great many researches which would come to the Institute would ultimately yield such very large commercial returns as to justify the existence of such an institute, he was of the opinion, nevertheless, that many problems presented would be impossible of solution and that the donors of such fellowships would become discouraged, and that consequently, in the future, manufacturers might feel that while there was a chance for very large returns they would not be justified in spending the necessary money unless there was a considerable cer-

tainty of obtaining some return. Experience so far has shown that this was but a partial truth. A manufacturer will often present a problem which investigation proves to be so difficult as to be practically impossible of solution. It seems to be always the case, however, that, while the fellowship founded by a certain company may not be able to solve the original problem presented, there are so many other problems confronting manufacturers that very soon the problem is found which can be solved; and very often the manufacturer himself does not realize until after an investigation is started just what his problems are and just what improvements and savings can be made in his manufacturing processes. The net result of these facts has been that the fellowships are almost uniformly successful. I feel firmly convinced, from the experience in this work, that almost any manufacturer having a trained man give his whole time and attention to the problem and difficulties of his particular company, through the excellent facilities of the Institute and its accumulated experience in meeting such, is practically certain to reap a greater monetary return than the amount of money expended in the investigation, and that in very many cases he will obtain results of such far-reaching importance that the ultimate reward may be many times the outlay.

It is perhaps advisable to consider the relation of the Mellon Institute to the commercial chemist. In this connection I do not know how I could do better than to quote the head of one of the largest commercial laboratories in the country, who, in speaking on this matter, said: "Research is like dipping up the ocean with a spoon"—unending; the more good research that is done in this country the more will be the demand for research and the more will all chemical business be stimulated. The Institute does not attempt to take up any questions which might be denominated as of strictly routine character. It does no analyses and does no work that does not involve new things—that is, real research. It is not, therefore, in any sense a competitor of commercial laboratories, so far as the major portion of their work is concerned. There are now in this country a few commercial laboratories which are specializing in high-grade research work. In a certain sense the Mellon Institute might be considered as a competitor to these laboratories; looked at in a broader way, it might be con-

sidered as an advance sales-agent of all these laboratories, as one of the principal aims of the Institute is to demonstrate to manufacturers the value of research—and all good research will mean more and more research. It is getting to be a well-recognized principle in business that in the pioneer work of the introduction of a totally new class of products there will be, because of the multiplied publicity, more business for each of several firms than for one firm, especially where the product has a practically unlimited market, as in the case of research. And, of course, in its broader aim of making American industry more efficient in its manufacturing practices, the Institute will stimulate all American chemistry, as efficient industry means continual control in all stages of manufacture. No man can foresee what will be the ultimate end of a great idea such as that conceived by Professor Duncan and developed by him into the Mellon Institute. It is fairly well recognized that the experimental stage has long since passed, and I have attempted in this article to give the present status of the work and to explain some of the manifold relations of this system to industry and to science.

For the sake of the scientific world, it is perhaps unfortunate that the results obtained under these Fellowships may not be published at once; while the agreements under which Industrial Fellowships are founded provide for eventual publication, this can be done only at such time as will not unduly injure the interests of the donating companies. It will be recognized by all, however, that those who pay for the investigations should own the results. For that reason, most of the important work done in the Institute to date has not yet been published. Many of the by-paths which appear in every investigation yield results of scientific interest, and a number of papers detailing the results of work of this character have been published by the Institute, a list of which is herewith appended.

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Selenium Glasses. O. N. WITT and FRÄNKEL. (*Sprechsaal*, xlvii, 444.)—Referring to Fenaroli's work, a knowledge of the colloidal nature of the coloring agent is regarded as less important than the proportion of selenium introduced to that which actually stains. The total selenium present was estimated by the amount of iodine it liberated from potassium iodide after the glass had been treated with hydrofluoric acid. The chromogenic selenium was estimated colorimetrically by comparison with a colloidal solution obtained by reducing selenium dioxide with gelatin and phosphoric acid. The figures obtained were: Selenium introduced, 0.0262; Se found, 0.021; chromogenic Se, 0.0016 per cent., a proportion of 100:8. Temperature influences the color obtained; at 620° C. a selenium glass was rendered colorless, but returned to its original tint on cooling. In glasses containing potash the color tends to brown, the more basic the composition. If potash be completely replaced by soda, a selenium glass is colorless. The maximum content of selenium in alkali-lime glasses is said to be 0.06 per cent.; above this limit volatilization occurs. In alkali-lead glasses a much higher content is possible, owing to the formation of lead selenide, which colors the glass dark brown. As selenium in the free state begins to volatilize at 120° C., it should be introduced as selenite or selenate. In the subsequent discussion the use of selenium as a coloring agent in the ceramic industry was approved and recommended.

Thermo-electric Power of Tin Selenides. H. PÉLABOU. (*Comptes Rendus*, clviii, 1897.)—SnSe forms a couple with platinum in which the current travels from the platinum toward the selenide across the hot junction. With temperatures of 0° and 100° C. the potential difference is -0.033 volt, and for temperatures of 0° and 580° C. it is -0.2 volt. SnSe₂ gives values of the same magnitude but of opposite sign up to 600° C.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A VIBRATION ELECTROMETER.

By Harvey L. Curtis.

[ABSTRACT.]

ANY alternating current measurement which makes use of a null method requires an instrument which will detect small alternating currents or voltages. One of the first instruments used for this purpose was the telephone. This is very sensitive between the frequencies of 500 and 3000 cycles per second, but at frequencies below 500 cycles the sensitiveness decreases rapidly with the frequency, so that it is very insensitive at frequencies below 100 cycles. It also responds to the harmonics of the current as readily as to the fundamental.

As a null instrument, a vibration galvanometer is often much more satisfactory than a telephone. The moving system of a vibrating galvanometer is adjusted to have the same period as that of the current to be detected, so that any harmonics in the current produce very little effect upon the deflection of the instrument. Also, most vibration galvanometers have their maximum sensitiveness at low frequencies (50 to 200 cycles), though at least one form may be had which will go to frequencies as high as 3000 cycles. Since the impedance of these instruments is relatively low, they require an appreciable current to produce a deflection which can be observed. Hence in bridges where the impedance of the arms is very high they are not very sensitive.

The vibration electrometer described in this paper was designed as a vibrating instrument having an impedance much higher than a telephone or vibration galvanometer. The need arose in connection with the measurement of some very low capacities at low frequencies. Its usefulness is limited to those cases where it is desired to detect very small currents at low frequencies. Its principal use is as a detecting instrument in a bridge having very high impedances in the arms.

The instrument is a modification of a quadrant electrometer. Instead of the quadrants there are four vertical plates, while a thin vertical vane of twice the area of a single plate corresponds

* Communicated by the Bureau.

to the needle of the electrometer. Two plates, separated by a narrow vertical slit, are in one plane, while opposite them in a parallel plane are the other plates. Midway between the planes is the aluminum vane which is suspended by a bifilar suspension. This vane is maintained at constant potential by a battery, while an alternating voltage having the same period as the natural period of the vibrating system is applied to the plates. This causes mechanical forces to be applied to the vane due to electrostatic attractions and repulsions which will set the vane in vibration. Since these forces are small, it is necessary that the damping shall be small. In addition to so designing the suspension that there is very little loss of energy in it, it is necessary to keep the instrument in a vacuum.

The form of the instrument is such that the capacities can be approximately computed. Hence it is possible to develop the mathematical theory of its behavior. This has been done, and the conclusions reached have been checked by experiment. The important conclusions are as follows:

1. The frequency at which maximum deflection is obtained depends upon the potential of the vane. As the potential of the vane is increased, the frequency at which maximum deflection is obtained is decreased.

2. The deflection for a given voltage is inversely proportional to the damping.

3. As the damping is decreased, the tuning becomes sharper.

4. The power required to give unit deflection when the applied electromotive force is in resonance with the instrument decreases in the same ratio as the damping.

Experimentally it has been found that the instrument will detect a current as low as 10^{-12} ampères.

ELECTRICAL RESISTANCE AND CRITICAL RANGES OF PURE IRON.*

By G. K. Burgess and I. N. Kellberg.

[ABSTRACT.]

THE exact determination of the variation of the electrical resistance of pure iron (99.98) in terms of temperature has been made over the range 0 to 950 ° C., particular attention being

* Scientific Paper.

given to the form of the curve over the A₂ and A₃ critical ranges. It was found possible to adapt the apparatus for determining heating and cooling curves described in Scientific Paper No. 213 to the determination of the resistance of iron in terms of that of platinum by the medium of a very sensitive Wheatstone bridge and the above-mentioned cooling apparatus. The iron and platinum thermometers were enclosed side by side *in vacuo* within a quartz tube, and it was possible to determine the resistance curve to a precision of 1 in 1,000,000 or to 0.005° C. No anomalies are found in the resistance of iron until the A₂ region is approached, and at A₂ there is an inflection at 757° C. in the resistance temperature curve shown as a sharp cusp in the temperature coefficient. At A₃ the resistance of iron falls abruptly by some 0.005 of its value, which is recovered within a 25° interval, and above A₃ it increases greatly again. On cooling, the A₃ is accompanied by slight increases of resistance with falling temperature. A₃ and A₃ begin at the same temperature, 894° C., and each extends over a temperature interval of 25°. These resistance measurements show that A₂ is a strictly reversible transformation and A₃ is a transformation taking place at a higher temperature on heating than on cooling. These experiments are in agreement with the thermal observations previously recorded in Scientific Paper No. 213.

Whether or not either or both of these critical ranges A₂ and A₃ are to be considered allotropic points will depend upon the definition of allotropy, about which there does not appear to be agreement.

THE HYDRATION OF PORTLAND CEMENT.

By A. A. Klein and A. J. Phillips.

THE study of the hydration of Portland cement follows as a natural sequence to the study of its constitution. The latter has been determined by the work of the Geophysical Laboratory on the ternary system lime-silica-alumina, and for that portion of the ternary field in which Portland cement is situated these compounds have been verified by the Pittsburgh laboratory of the Bureau of Standards.

In the present paper various hydration experiments were made on monocalcium aluminate ($\text{CaO} \cdot \text{Al}_2\text{O}_3$), 5:3 calcium alu-

minate ($5\text{CaO} \cdot 3\text{Al}_2\text{O}_3$), tricalcium aluminate ($3\text{CaO} \cdot \text{Al}_2\text{O}_3$), mono-calcium silicate ($\text{CaO} \cdot \text{SiO}_2$), beta-ortho-silicate ($2\text{CaO} \cdot \text{SiO}_2$), gamma-ortho-silicate ($2\text{CaO} \cdot \text{SiO}_2$), and tri-calcium silicate ($3\text{CaO} \cdot \text{SiO}_2$), lime burned at different temperatures and ground to various degrees of fineness, and on the following commercial cements, a high silica, a low silica, a high iron, and a high magnesia cement.

The tests consisted of (1) hydration on microscopic slides with water, without access of air; (2) hydration with superheated steam in a cylinder, according to the method proposed by Bied; (3) hydration in an autoclave, and (4) moulding with limited quantities of water, approximating those used in normal consistency mixes. Lime water and plaster-of-Paris solution were also used as hydrating mediums. Petrographic methods were employed to determine the hydration processes and the final products.

The only crystalline product observed in the hydration of the aluminates was hydrated tri-calcium aluminate ($3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$), and this is only formed with a large excess of water. It crystallizes in hexagonal needles, plates, and spherulites, and is uniaxial positive. The refractive indices are $= 1.552 - .003$ and $= 1.535 - .003$. The 5:3 calcium aluminate and mono-calcium aluminate split off amorphous hydrated alumina and form the crystalline hydrated tri-calcium aluminate. The hydration of the aluminates commences quickly in all cases, but with restricted amounts of water the unhydrated grains become coated with the amorphous form and further hydration is more or less retarded, this amorphous form slowly changing to the crystalline form. With steam at atmospheric pressure the weakly basic aluminates do not hydrate above 110° , but the more basic ones absorb water up to 140° , tri-calcium aluminate containing high-burned free lime absorbing water even at 175° .

The hydration of the aluminates in lime water reveals no new products, but in plaster solution, in addition to the same compounds formed with water, there is a compound observed with a formula $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot x\text{H}_2\text{O}$ — tri-calcium sulpho-aluminate, usually referred to in cement literature as “sulpho-aluminate.” This compound is identical for three aluminates and crystallizes in long prismatic needles. The double refraction is low, the character of the principal zone negative, and the extinction

parallel. The indices of refraction are less than 1.48. It is biaxial positive with a large optic axial angle. Its formation is only incidental in the retardation of the initial set caused by gypsum. In the autoclave, crystals of both the sulpho-aluminate and gypsum are destroyed.

Burned lime hydrates with an excess of water to either the crystalline or amorphous form of lime hydrate. A preponderance of the former is produced where the lime is coarse and high-burned, while the formation of the amorphous form is favored by fine grinding and low burning. Crystallized lime hydrate occurs as flaky hexagonal crystals or as hexagonal prisms with excellent cleavage parallel to (.0001). It is uniaxial negative and the refractive indices are $=1.581-.002$ and $=1.559-.002$. In the autoclave amorphous lime hydrate does not change to the crystalline form, but free lime may yield crystals of hydrate whose size depends upon the length of time of reaction, temperature, and pressure.

The mono-calcium silicate and the gamma-ortho-silicate do not hydrate, while the beta form of the latter hydrates but slightly with water after long periods. Lime water and plaster solution do not materially increase the hydration, whereas a solution of the calcium aluminate gives the maximum hydration and best-appearing test pieces. The 28-day test pieces of beta-ortho-silicate and the aluminates, while exhibiting fairly good rigidity, have by no means the strength of corresponding neat cement briquettes. The aluminates are completely hydrated, but the beta-ortho-silicate shows only a comparatively slight hydration. The hydration product of the silicate is amorphous hydrated ortho-silicate, there being no lime hydrate split off and no needles of hydrated mono-calcium silicate formed, as noted by others.

The tri-calcium silicate hydrates readily and quickly with all concentrations of water, the products of hydration being crystallized lime and amorphous hydrated ortho-silicate. Moulded specimens set hard in 5 hours and show no disintegration after 28 days in water. It has no favorable effect on the hydration of beta-ortho-silicate. Mixtures of it and the aluminates show first the beginning of hydration of the aluminates, followed shortly by the hydration of the silicate. Moulded specimens of these are dense, hard, and strong, comparing very favorably with neat cement briquettes.

On the hydration of cement, the first constituent to react is the aluminate, with the formation of amorphous hydrated tri-calcium aluminate, with or without amorphous hydrated alumina. The sulpho-aluminate crystals are also formed, and the low-burned or finely-ground lime hydrates. This occurs within a few hours after the cement is gauged. The next compound to hydrate is the tri-calcium silicate. This commences within 24 hours, and is generally completely hydrated within 7 days. Between 7 and 28 days, the amorphous aluminate commences to crystallize and the beta-ortho-silicate, the least reactive compound, begins to hydrate. The 24-hour strengths are due mainly to the hydration of the aluminates and of any fine-grained, low-burned lime present. The large increase in strength between 24 hours and 7 days is due mainly to the tri-calcium silicate hydration. The increase between 7 and 28 days is due to the hydration of the beta-ortho-silicate. Where there is a decrease in strength during this period it is due to the hydration of very high-burned free lime, as in very high-burned, high-limed cements, or to the crystallization of the aluminates, as in high alumina cements. The iron compounds in a cement are resistive to hydration. It does not form crystalline hydration products, but occurs as a rust-like material.

The initial set of cement is affected by the action of small amounts of electrolytes in retarding coagulation of the aluminate material. With a limited amount of water, such as used in normal consistency mixes, the aluminates coagulate and separate from supersaturated solutions as amorphous bodies, the rate of coagulation being affected by such small quantities of electrolyte as to nullify the possibility of the reaction being solely a chemical one.

Failure of cement in accelerated tests is due to the growth of large lime hydrate crystals. The disrupting action results from the pressure caused by growing crystals. Cement will fail in the boiling test which contains lime sufficiently fine and high burned, so that during boiling it hydrates and crystallizes. The growth of crystals is sufficient to cause disintegration. When a cement passes the boiling test but not the autoclave test, it contains lime so coarse or high burned as not to hydrate in the boiling test, but only in the autoclave, due to the high temperature and pressure employed. Some cements will pass either test only after aging. In this case aëration with insufficient water to allow solu-

tion and crystallization causes the lime to hydrate as amorphous hydrate, and in the accelerated tests there is no crystallization and no disintegration.

The reactions when cement is subjected to the autoclave test are not abnormal. The disintegration action attributed to the crystallization of the sulpho-aluminate has been greatly exaggerated.

THE LEAD ACETATE TEST FOR HYDROGEN SULPHIDE IN GAS.*

By R. S. McBride and J. D. Edwards.

THE effect of the following factors upon results obtained in tests for the detection of hydrogen sulphide in gas by the lead acetate test have been investigated: (1) The paper: Kind; method of its preparation, including the strength of lead acetate solution used; and the moisture content when used. (2) The gas: Its humidity, and the period and rate of flow. (3) The apparatus: Its form and size, as determining the circulation of gas with respect to the paper. With gas mixtures containing various known amounts of hydrogen sulphide these several factors were studied one at a time and the following conclusions reached.

An operator, by giving consideration to the desirable qualities which are pointed out, can easily select the most suitable and convenient kind of paper after a trial of a number of samples; the convenience, but generally not the accuracy, of the test is affected by the choice. There is little or no difference in the sensitiveness of the paper prepared with lead acetate solution from 2 to 12 per cent. in strength; a 5 per cent. solution is recommended. Treatment of the papers with ammonia or carbon dioxide does not materially change their sensitiveness. It is recommended that the test paper be dipped in lead acetate solution, blotted, and used moist, since such paper gives the most reliable results.

The large effect of the humidity of the gas upon the test results is shown; but it is also noted that the use of moist paper with short test periods (not over 3 minutes) gives results practically independent of the humidity of the gas. It is impracticable either to dry or to saturate the gas to a constant condition

* Technologic Paper 41 of the Bureau.

as to humidity, because of the probability of simultaneous change in the hydrogen sulphide content.

The rate of gas flow is shown to have some effect, but increases in rate produce less effect than proportional increases in the time of test. The general practice of making tests at 5 cubic feet per hour is satisfactory; maintenance of the rate within the limits 4.5 and 5.5 cubic feet per hour is sufficient.

The time of test is an important factor in determining its sensitivity; the proper basis for selection of the length of test is treated in connection with the discussion of the quantitative and engineering significance of the test.

The different forms of testing apparatus used may be classified into three groups—circulating, impinging, and penetration—these being distinguished by the manner in which the gas is brought into contact with the paper. The five forms of circulating apparatus tested were: The simple hydrogen sulphide tester, chosen for this work and designated in this paper as standard apparatus; the Referees apparatus; the Young's sulphur and ammonia test apparatus; the small drying-tower form; and a large Woulff bottle. Only one very simple form of the impinging type was tested; and a single penetration apparatus, devised by the authors, was used.

The variation in the test with different forms of apparatus is largely due to the variation in intensity of the gas currents and their direction in relation to the paper. In the small drying tower the test paper was suspended close to the rubber stopper bearing the burner, and a much larger proportion of the gas came in contact with the paper than in the other forms of apparatus. Although the Woulff bottle had a larger capacity than the Referees apparatus, it consistently gave a stronger test than the latter, showing that size alone is not a determining factor; the shape of the apparatus and the location of the paper relative to the inlet and outlet have an important influence.

It has been generally recognized that a test in which the gas impinges on the paper is more sensitive than one in which the gas does not impinge; this is due to the better opportunity for contact of the gas with the reagent on the paper and to the small area within which the lead sulphide is concentrated. And a similar increase in sensitiveness is accomplished by causing the gas to be tested to pass through the paper, as is done in the penetration

apparatus described. This increase in sensitiveness due to impingement of gas on paper seems to have been overestimated by some, however.

The important influence of the shape and size of the apparatus upon the result of tests made with it makes clear the necessity of an exact specification of the form and size of the tester. It is therefore recommended that the specifications given for the apparatus which is used as standard in this work be followed exactly in making the tests.

When the test is made under definite conditions, the coloration produced is of quantitative significance, as indicating the amount of hydrogen sulphide present in the gas. The results which are obtained by the procedure recommended as standard are shown to have the following significance: The test, if of 1 minute duration, will detect about 0.3 to 0.4 grain hydrogen sulphide per 100 cubic feet of gas. But if the test is of 0.5 minute duration, about 0.45 grain of hydrogen sulphide is required to give a test; if extended to 3 minutes, a gas of about 0.2 grain will give positive results. The Young's apparatus is slightly more sensitive than the standard form, but the Referees apparatus is less sensitive, for it will scarcely detect 0.5 grain of hydrogen sulphide per 100 cubic feet of gas when used with moist paper for 3 minutes at a rate of 5 cubic feet of gas per hour.

The penetration apparatus is somewhat more sensitive than any of the forms of circulating apparatus. The sensitivity of the apparatus of the impinging type is variable, depending upon the rate of gas flow, distances of jet from paper, etc.; but under the most favorable conditions apparatus of this type is the most sensitive of all.

No direct comparison can be made with the work of some of the previous observers, but it is certain that too great a sensitivity has been ascribed to the procedures used by these experimenters.

The commercial significance of the testing procedures recommended is pointed out. It is stated that many tests of similar severity, and some a great deal more severe, have been met regularly in the past, showing that the proposal is certainly not unreasonable.

The method recommended for use is quick and convenient and gives reproducible results; and a simple and inexpensive form of apparatus is described which can easily be constructed by

inexperienced persons without any sacrifice of the advantages due to exactness of specifications. The importance of conforming with the specifications, both as to the apparatus and the procedure in testing, is pointed out.

MEASUREMENT OF TIME AND TESTS OF TIMEPIECES.*

THE test and certification of watches, chronometers, and other timepieces has been carried on for many years at the Kew Observatory in England, at the Besançon Observatory in France, and at the observatories of Geneva and Neuchatel in Switzerland, but no such tests have been made for the public in this country, except for a few years at Yale University, many years ago. This line of work is now started at the Bureau of Standards, and a circular under the above title is being issued, giving the regulations under which the tests will be made, the methods employed, together with sections on the use and care of watches, and on standard time and the sources of reliable time standards with which one may make frequent comparisons of his watch. This first edition of the circular announces the regulations for the test and certification of watches only; the test of other timepieces will be taken up later.

For the purposes of test, watches are divided into two classes, designated as A and B, adapted to watches adjusted for five positions and three positions respectively. The former test lasts 54 days, the latter 40 days. Both tests include a test of the temperature compensation of the watch, at temperatures of 5°, 20°, and 35° C. In the Class A test is also included an examination of the isochronism adjustment of the watch. Four tests a year are carried out, beginning on the second Tuesday in January, April, August, and October respectively. The daily rates of the watches under the various conditions are determined within about 0.1 second. If the performance of a watch is within certain tolerances set for the different conditions, a certificate is granted showing the results of the test. If a watch fails to meet the requirements, a report is rendered showing wherein it fell short of the tolerances and giving its actual performance in the trial. Watches may be submitted by manufacturers or jobbers of

* Bureau Circular No. 51.

watches, by retail dealers, or by the individual owners of the watches, a fee being charged which is estimated to cover the actual cost of the test. It is expected that the tests will be especially valuable in cases where watches are to be used for scientific purposes or exploration, and also to purchasers of high-grade watches in giving them assurance that the watch is reasonably adjusted and in good condition at the time of test. Copies of the circular and also of the application blank which must be filled out by those submitting a watch for test may be obtained upon request directed to the Bureau of Standards, Washington, D. C.

Collision of α -Particles with Light Atoms. C. G. DARWIN. (*Phil. Mag.*, xxvii, 499.)—The large angle deflections of α -particles led to Rutherford's hypothesis of atomic constitution, but his calculations involve the assumption that the atom is so heavy as to remain sensibly unaffected by the collision. The author modifies and extends Rutherford's work by removing this restriction. Calling M the mass of the particle, and m that of the atomic nucleus, there are three cases to consider, according as m is greater than, equal to, or less than M , when γ is the number of α -particles with deflection φ observed within a solid angle ω , an expansion is obtained for γ as a function of φ and M/m , and in powers of the latter. *First case:* $m > M$. This applies to all substances except helium and hydrogen. The first term of the expression gives Rutherford's expression. If M/m were as high as $1/3$, as it would be for carbon, the velocity of the carbon nucleus might rise as high as $V/2$, V being the initial velocity of the α -particle. Such a particle might possibly be perceptible, but it is doubtful whether the shock would free the nucleus of all its electrons; thus the experimental conditions to reveal it are rather hard to imagine. *Second case:* $m = M$. The α -particle now travels through helium. In this case no particle can be deflected through more than a right angle, and to the number of α -particles must be added the He-atoms which have been set in motion so as to strike the screen, for the recoiling particles should be quite indistinguishable from the true α -particles. *Third case:* $m < M$. The α -particles travel through hydrogen, and $m = M/4$. The number of particles, as observed by the scintillations, will be composed of particles of three types, slow α -particles, fast α -particles, and the recoiling H-particles, which will move more rapidly than either of the other groups. In passing through matter these will be retarded like α -particles, and Bohr's formula shows that the range of an H-particle will be slightly less than an α -particle of the same initial velocity. Bohr's formula ceases to hold for small velocities, but Geiger's empirical formula $V^3 = V_0^3(1 - X/R)$ leads to the conclusion that, corresponding to a range of 31 cm.

of an α -particle, the range of an H-particle will be 28 cm. If an α -particle from RaC at its highest velocity strikes a nucleus straight on, the initial velocity of the H-particle will be $8/5 \times 2 \times 10^9$ cm. per second, and its range comes out at 117 cm. It would probably be greater than this, as at high speeds the range should be more nearly proportional to V^4 than to V^3 . The H-particles, therefore, should be easily observable if they can be made to occur in sufficient numbers. Their scattering should be greater than for α -particles, for the most probable angle of scattering depends upon E/M , and so is twice as great for H- as for α -particles. Geiger and Marsden's experiments are strongly confirmative of the nuclear hypothesis, and no force proportional to the power of the distance other than the inverse square can give the observed relation between γ and V . An upper limit to the size of atomic nuclei is calculated from the distance of closest approach between the α -particle and the nucleus. For gold the number of deflections was observed up to $\varphi = 150^\circ$, and found correct. Taking the charge of the nucleus as 100 times the electronic charge, and $V = 2 \times 10^9$ cm. per second, gives 3.5×10^{-12} cm. as closest approach. In a straight-on collision with an H-nucleus it would be 1.7×10^{-13} cm., which leads to the result that the radii of the nuclei H and He are certainly less than 10^{-13} cm.

Two New Modifications of Phosphorus. P. W. BRIDGMAN. (*J. Amer. Chem. Soc.*, xxxvi, 1344.)—Ordinary white phosphorus is converted into another modification, white phosphorus II, at about -76.9° C. under atmospheric pressure, the change being reversible; the crystalline form of the product is probably hexagonal. A second modification—black phosphorus—is irreversibly formed by heating white phosphorus to 200° C. under a pressure of 12,000 Kilos per square centimetre. Black phosphorus has a density of 2.691, is not spontaneously inflammable, and is a fairly good conductor of heat and electricity. It has a lower vapor pressure and probably a somewhat higher melting-point than red phosphorus; red and black phosphorus appear to yield identical liquids when melted.

Action of Radium Rays on Bakelite. C. E. S. PHILLIPS. (*Nature*, xciii, 295.)—A disc 4.2 mm. thick of the light yellow variety of transparent bakelite was cut from a rod, polished, and then radiated with β - and γ - rays from radium. The color of the disc darkened to a wine-red after three days, and exhibited an absorption band λ - 5700 to 6000, which was not visible at first. The spectrum beyond λ 4900 Å. was also obliterated. The coloration extended to a depth of 2 mm., and it could be completely removed by exposure to a temperature of 100° C. for about three hours. The effect appears due to the direct action of the β - rays, and the author suggests that the new substance may prove to be a useful filter for therapeutic use, especially as it is cleanly and easy to work.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, October 21, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 21, 1914.

VICE-PRESIDENT COLEMAN SELLERS, JR., *in the Chair.*

Additions to membership, 22.

Mr. George R. Henderson, Chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

The Chairman then introduced Dr. L. A. Bauer, Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C., who presented a communication on "The Earth, a Great Magnet." The speaker gave the chief facts and latest results pertaining to the earth's magnetism, based largely upon the general magnetic survey of the earth, begun by the Department of Terrestrial Magnetism of the Carnegie Institution in 1904 and now two-thirds completed. The cruises of the non-magnetic ship *Carnegie* and the instrumental appliances and methods used in the observational work were described. An account was also given of the various expeditions sent under Dr. Bauer's direction to distant and more or less unexplored countries. The lecturer discussed the possible bearing of researches in terrestrial magnetism on other mooted questions in terrestrial and cosmical physics.

Experiments and lantern slides were used to illustrate the subject. The Chairman conveyed the thanks of the audience to the speaker.

The meeting then adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
October 7, 1914.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 7, 1914.

MR. L. E. LEVY, *Chairman pro tem.*

The following reports were presented for first reading:

No. 2584.—The Humphrey Pump.

No. 2595.—Dr. W. W. Strong's Dust, Smoke and Fume Indicator.
Advisory. Adopted.

The following report was presented for final action:

No. 2605.—Blonck Boiler Efficiency Meter. Certificate of Merit.
Adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the section was held in the Hall of the Institute on Thursday, October 1, 1914, at 8 o'clock P.M., with Dr. Harry F. Keller in the chair. One hundred and fourteen members and visitors were present. Dr. Max von Recklinghausen, of the R. U. V. Company, New York City, delivered an address on "The Ultra-Violet Rays and Their Application for the Sterilization of Water." The various sources of ultra-violet light were discussed, and a detailed description was given of the construction, mode of operation, and light emanations of the mercury-vapor quartz lamp. The physical, chemical, and biological phenomena produced by ultra-violet rays were enumerated, as were the various methods of measuring the rays physically, chemically, and biologically. The history of the application of the rays for the sterilization of water was traced; and the development of modern apparatus for this purpose was described, together with the results obtained on a commercial scale.

The paper was discussed at length, a vote of thanks was extended to Dr. von Recklinghausen, and his work referred to the Committee on Science and the Arts. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mining and Metallurgical Section.—A joint meeting of the American Society of Mechanical Engineers and the Mining and Metallurgical Section of The Franklin Institute was held in the Hall of the Institute on Thursday, October 8, 1914, at 8 o'clock P.M.

Prof. H. E. Ehlers, member of the society, and Prof. A. E. Outerbridge, Jr., president of the section, presided jointly.

Professor Outerbridge introduced the speaker of the evening, Mr. J. E. Johnson, Jr., Consulting Engineer and Metallurgist, New York, N. Y., who presented a paper entitled "Recent Developments in Cast Iron Manufacture."

Mr. Johnson discussed the results of carbon, silicon, sulphur, phosphorus, oxygen, and manganese in cast iron. He outlined investigations, made at the Ashland Plant of the Lake Superior Iron and Chemical Company, in which it was disclosed that the presence of oxygen accounted for the superiority of charcoal iron over coke iron. He described experiments made to introduce oxygen into iron and convert coke iron into a product he considered superior to charcoal iron, and gave the physical properties of an iron of composition: Combined carbon, 0.85 per cent.; graphitic carbon, 2.65; manganese, 0.26; phosphorus, 0.326; sulphur 0.039; silicon, 1.25; oxygen, 0.50. Photomicrographs of the structure of this iron were shown.

The paper was discussed by several members present.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Section of Photography and Microscopy.—A joint meeting of the Photographic Society of Philadelphia and the Section of Photography and Microscopy was held in the Hall of the Institute on Thursday evening, October 15, at 8 o'clock.

Dr. Henry Leffmann, president of the section, occupied the chair.

The Chairman reviewed briefly the work of the section and called attention to the important papers on photographic subjects to be presented during the present season as part of the programme of lectures arranged by the Secretary of the Institute.

He then delivered a lecture on "Recent Advances in Photographic Chemistry." He showed some early slides made by impressing woodcuts on the surface of gelatin and enclosing the latter between sheets of glass. He illustrated the effects produced on sensitized plates by exposing them for a length of time in the dark near, but not touching, various metals and some other substances, such as quartz, collodion, etc. He described the production of photographs of printed matter, using luminous plates as the source of light.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting, Board of Managers, October 14, 1914.)

RESIDENT.

MR. R. B. CAVERLY, 529 Lincoln Drive, Germantown, Philadelphia, Pa.

MR. LESLIE M. WEBB, Wedge Mechanical Furnace Company, Greenwich Point, Philadelphia, Pa.

NON-RESIDENT.

MR. R. C. M. HASTINGS, The International Telephone Company, Columbus Savings and Trust Building, Columbus, Ohio.

MR. JOHN V. H. DORR, 30 Church Street, New York, N. Y.

Changes of Address.

MR. WALTER ATLEE, 2112 Eighteenth Street, Washington, D. C.

MR. JOHN CALDER, 25 Merriam Street, Lexington, Mass.

MR. EDWARD C. CARTER, 412 Greenwood Boulevard, Evanston, Ill.

MR. HAROLD V. COES, The Sentinel Automatic Gas Appliance Company, New Haven, Conn.

MR. F. WINSOR EVELAND, 6307 Sherwood Road, Philadelphia, Pa.

MR. PENROSE R. HOOPES, 1015 South Farragut Terrace, Philadelphia, Pa.

MISS EMILY E. HOWSON, Lake Erie College, Painesville, Ohio.

MR. E. KELLER, 720 Jefferson Avenue, E., Detroit, Mich.

MR. HUGO LIEBER, 14 Platt Street, New York, N. Y.

MR. FRANK M. MASTERS, 101 Park Avenue, New York, N. Y.

MR. J. W. WALKER, Port Kennedy, Pa.

MR. TINIUS OLSEN, The Gladstone, Eleventh and Pine Streets, Philadelphia, Pa.

MR. ALLEN WOOD, 3rd, Flat Rock, N. C.

NECROLOGY.

MR. Henry Brinton, 2408 Bryn Mawr Avenue, Bryn Mawr, Pa.

MR. J. Clifford Brooks, care of Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Pa.

Prof. W. L. Dudley, Vanderbilt University, Nashville, Tenn.

MR. Alfred Jones, The Wadsworth, Boston, Mass.

MR. Arnold Nacke, 240 South Ninth Street, Philadelphia, Pa.

MR. Kurt W. Peuckert, Sharon Hill, Delaware County, Pa.

LIBRARY NOTES.

Purchases.

American Electrochemical Society.—Transactions, vol. 25. 1914.

BUEHLER, F. A.—Filters and Filter Presses for the Separation of Liquids from Solids. 1914.

COX, JOHN.—Mechanics. 1909.

HALSEY, F. M.—Railways of South and Central America. 1914.

HOFMAN, H. O.—General Metallurgy. 1913.

HORNER, JOS. G.—Practical Iron Founding. 1914.

IVENS, EDM. M.—Pumping by Compressed Air. 1914.

LEBLANC, MAX.—Text-book of Electrochemistry. 1913.

MINERAL INDUSTRY, volume 22. 1913.

RANDALL, J. A.—Heat—A Manual for Technical and Industrial Students. 1914.

STROHM, RUFUS T.—Oil Fuel for Steam Boilers. 1914.

WAGNER, FREDERIC H.—Cleaning of Blast-furnace Gases. 1914.

Gifts.

Alberger Pump and Condenser Company, Catalogue E. New York, 1914. (From the Company.)

American Blower Company, 19 Bulletins: A Treatise on Shop Heating; Publication No. 343. Detroit, Mich., no date. (From the Company.)

American Rolling Mill Company, Defeating Rust; Iron Roofs that Resist Rust. Middletown, Ohio, no date. (From the Company.)

American Society for Testing Materials, Charter and By-Laws and Membership List—Circular No. 92. Philadelphia, 1914. (From the Society.)

American Spiral Pipe Works, Catalogues. Chicago. (From the Company.)

Armstrong Cork Company, four Catalogues. Pittsburgh, 1914. (From the Company.)

- Atlas Portland Cement Company, Concrete Houses and Cottages, vols. i and ii: Concrete in Highway Construction—Concrete Construction for the Home and the Farm—Reinforced Concrete in Factory Construction—Concrete in Railroad Construction. New York, no date. (From the Company.)
- Ball Bearing Company, S. K. F., four Catalogues. New York, no date. (From the Company.)
- The Berger Manufacturing Company, Catalogue 19, Steel Ceilings. Philadelphia, Pa., no date. (From the Company.)
- Bernard Gloekler Company, Catalogues of Refrigerators. Pittsburgh, Pa., no date. (From the Company.)
- Boston Gear Works, Boston Gears. Norfolk Downs, 1914. (From the Works.)
- Boston Society of Civil Engineers, Year Book, 1914-1915. Boston, Mass., 1914. (From the Society.)
- Brown Hoisting Machinery Company, Tramrail Systems, Trolleys, Electric Hoists—Catalogue D. Cleveland, 1914. (From the Company.)
- Buffalo Foundry and Machine Company, Catalogue on Vacuum Apparatus. Buffalo, N. Y., no date. (From the Company.)
- Buffalo Wire Works Company, Catalogue No. 6. Buffalo, no date. (From the Company.)
- Busch-Sulzer Bros., Diesel Engine Company, The Diesel Engine. St. Louis, 1913. (From the Company.)
- Canada Agricultural Experimental Farms, Reports for year ending March 31, 1913. Canada, 1914. (From the Farms.)
- Canada Department of Mines: Memoirs 19, 39, 40, 47. Ottawa, 1913. Victoria Memorial Museum, Bulletin No. 2. Ottawa, 1914. (From the Department.)
- Canada Department of Trade and Commerce, Report, 1913, part 5. Ottawa, 1914. (From the Department.)
- Canadian Pacific Railway Company, Annual Report, 1914. Montreal, 1914. (From the Company.)
- Canadian Society of Civil Engineers, Charter, By-Laws and List of Members. Montreal, Can., 1914. (From the Society.)
- Carlisle & Finch Company, Searchlight Projectors. Cincinnati, Ohio, no date. (From the Company.)
- Chandler & Taylor Company, Bulletins on Steam Engines and Steam Boilers. Indianapolis, Ind., no date. (From the Company.)
- Colorado Iron Works Company, Catalogue No. 12-F. Denver, Col., no date. (From the Company.)
- Connecticut Geological and Natural History Survey, Reports, Volume 4, Bulletins 16, 21, 1910-1913. Hartford, 1914. (From the Survey.)
- Crane Company, Pocket Catalogue No. 40. Philadelphia, Pa., 1914. (From the Company.)
- DeLaval Steam Turbine Company, Catalogue "B," DeLaval High Efficiency Centrifugal Pumps. (From the Company.)

- The Denver and Rio Grande Railroad Company, Twenty-eighth Annual Report. Denver, Col., 1914. (From the Company.)
- Diamond Expansion Bolt Company, Catalogue 285. New York, no date. (From the Company.)
- W. E. Dunn Manufacturing Company, Catalogue No. 15, Concrete Machinery. Chicago, Ill., no date. (From the Company.)
- Electric Storage Battery Company, Chloride Accumulator. Philadelphia, no date. (From the Company.)
- Frost Manufacturing Company, Catalogue "D," Plumbers' Supplies. Kenosha, Wis., 1914. (From the Company.)
- Fuse, D. & W. Company, Catalogue No. 15. Providence, R. I., 1911. (From the Company.)
- Gifford-Wood Company, Catalogue of Ice Elevators and Ice Tools. Hudson, N. Y., 1915. (From the Company.)
- Goldberg Company, Catalogue No. 11, Display Fixtures. New York, N. Y., no date. (From the Company.)
- Graver, William, Tank Works, Bartlett-Graver Water Softener and Purifier. Chicago, no date. (From the Company.)
- Great Britain Patent Office, Subject Lists—Sound and Light—Enamelling, Art Metal Work, etc.—General Physics. London, 1914. (From the Patent Office.)
- Harris Patents Company, Bulletin A. M. Philadelphia, no date. (From the Company.)
- Hayward Company, Catalogue Nos. 39, 40, 41, Digging and Excavating Machinery. New York, no date. (From the Company.)
- Hindley Gear Company, Catalogue No. 5. Philadelphia, no date. (From the Company.)
- Ingersoll-Rand Company, two Catalogues. Philadelphia, no date. (From the Company.)
- Institution of Civil Engineers, Minutes of Proceedings, vol. cxcv; Charter, By-Laws and List of Members. London, 1914. (From the Institution.)
- Knox Automobile Company. Catalogue. Springfield, Mass., no date. (From the Company.)
- Koehring Machine Company, Catalogue No. 19, Concrete Mixer. Philadelphia, 1914. (From the Company.)
- Lagondo Manufacturing Company, Catalogues of Fuel Saving Specialties. Springfield, Ohio, 1914. (From the Company.)
- Lake Mohonk Conference on International Arbitration, Twentieth Annual Report. Lake Mohonk, 1914. (From the Conference.)
- Leland Stanford Junior University, The Hemolymph Nodes of the Sheep—The Evolution of Brazil Compared with that of Spanish and Anglo-Saxon America. Stanford University, Cal. (From the University.)
- Lewis Institute, Bulletin Annual Register for 1913-14, Announcements for 1914-15. Chicago, Ill., 1914. (From the Library.)
- Link-Belt Company, Book No. 195, Newspaper Conveyors; Section "A" of Catalogue No. 110, The Original Ewart Detachable Link-Belt and Sprocket Wheels. Philadelphia, 1914. (From the Company.)

- Luitwieler Pumping Engine Company, four Catalogues. Rochester, no date. (From the Company.)
- Lupton's David, Sons Company, Lupton Products Service No. 8. Philadelphia, no date. (From the Company.)
- Lynn, Mass., Commissioner of Water and Water Works, Annual Report, 1913. Lynn, 1914. (From the Commissioner.)
- Manchester Steam Users' Association, Memorandum by Chief Engineer, 1913. Manchester, 1914. (From the Association.)
- Manhattan Electrical Supply Company, Mesco Products. New York, no date. (From the Company.)
- Matthews and Brother, Inc., Catalogue and Hand Book No. 9. St. Louis, Mo., 1914. (From the Company.)
- Mechanics' Institute, Bulletin, Catalogue Number 1913-1914. Rochester, N. Y. (From the Institute.)
- Merchants' Association of New York, Investigation of the Fire Department of New York. New York, 1908. (From the Association.)
- Metropolitan Water Board, Eleventh Annual Report. London, 1914. (From the Engineer.)
- Minneapolis, St. Paul and Sault Ste. Marie Railway Company, Twenty-sixth Annual Report. Minneapolis, 1914. (From the Company.)
- Moore & White Company, Friction Clutches. Philadelphia, 1915. (From the Company.)
- Muncie Oil Engine Company, General Catalogue No. 21, The Power Problem Solved. Muncie, Ind., 1913. (From the Company.)
- Murray Iron Works Company, five Catalogues. Burlington, Iowa, no date. (From the Company.)
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- Nevada University, Register 1913-1914. Reno, 1914. (From the University.)
- Newton Machine Tool Works, Catalogues 47 and 48. Philadelphia, Pa., no date. (From the Company.)
- New York, Ontario and Western Railway Company, Thirty-fifth Annual Report. New York, N. Y., 1914. (From the Company.)
- New York Public Service Commission for the First District, Proceedings, 1913. New York, N. Y., 1914. (From the Commission.)
- North Carolina Geological and Economic Survey, Economic Paper No. 35, Good Roads Days. Raleigh, N. C., 1914. (From the Survey.)
- Northampton Polytechnic Institute, Catalogue 1914-1915. London, 1914. (From the Institute.)
- Ohio State University, Bulletin No. 33. Columbus, Ohio, 1914. (From the University.)
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- Pennsylvania Topographic and Geologic Survey, Report No. 10. Harrisburg, Pa., 1913. (From the Commission and from Dr. E. V. d'Invilliers.)
- Philadelphia Bureau of Water, Annual Report, 1913. Philadelphia, 1914. (From the Bureau.)
- Philadelphia Engineers' Club, Directory, 1914. Philadelphia, no date. (From the Club.)
- Plume & Atwood Manufacturing Company, Catalogues on Electric and Gas Fixture Parts and Hardware Specialties. Waterbury, Conn., no date. (From the Company.)
- Raymond Brothers Impact Pulverizer Company, Catalogue No. 11, Grinding, Pulverizing and Separating Machinery. Chicago, 1914. (From the Company.)
- Reeves Pulley Company, Catalogue No. 7. Chicago, no date. (From the Company.)
- Rife Hydraulic Engine Manufacturing Company, Catalogue. New York, N. Y., no date. (From the Company.)
- Rock Island Manufacturing Company, Catalogues of Hardware Specialties. Rock Island, Ill., no date. (From the Company.)
- John A. Roebling's Sons Company, Catalogue. Trenton, N. J., no date. (From the Company.)
- Ruggles Machine Company, Ruggles Engines—Ensilage Cutters and Blowers. Poultney, Vt., no date. (From the Company.)
- Ryerson, Joseph T. and Son, The Ryerson Friction Saw—The Lennox Rotary Bevel Shears. Chicago, no date. (From the Company.)
- Safety Car Heating and Lighting Company, Electric Fixtures. New York, 1914. (From the Company.)
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- Stark Rolling Mill Company, Corrosion and its Cause. Canton, Ohio, no date. (From the Company.)
- Stow Manufacturing Company, Catalogue No. 14. Binghamton, N. Y., no date. (From the Company.)
- Stroudsburg Engine Works, Catalogue No. 9, Hoisting Engines. Stroudsburg, Pa., no date. (From the Company.)
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- Tasmania Geological Survey, Bulletin No. 15, The Stanley River Tin Field. Hobart, 1914. (From the Survey.)

- Titan Storage Battery Company, Titan Storage Batteries. Newark, 1914. (From the Company.)
- Trump Manufacturing Company, Trump Turbines. Springfield, no date. (From the Company.)
- U. S. Coast and Geodetic Survey, Results of Observation Made at the United States Coast and Geodetic Survey Magnetic Observatory near Tucson, Ariz., 1911 and 1912. Washington, 1914. (From the Survey.)
- U. S. Commissioner of Patents, Annual Report, 1913. Washington, 1914. (From the Patent Office.)
- United States Electrical Tool Company, Catalogue 11. Cincinnati, Ohio, 1914. (From the Company.)
- U. S. Geological Survey, Mineral Resources of the United States, 1912. Washington, D. C., 1913. (From the Department.)
- The United States Radiator Corporation, The Complete Line. Detroit, no date. (From the Corporation.)
- United States War Department, Annual Reports of Chief of Engineers, 1913. Washington, D. C., 1914. (From the Department.)
- Waterbury Tool Company, The Waterbury Hydraulic Speed Gear. Waterbury, Conn., 1914. (From the Company.)
- Western Australia Government Statistician, Statistical Register, 1912. Perth, 1914. (From the Statistician.)
- Western Electric Company, Bulletin Catalogue, Telephone Apparatus and Supplies. Philadelphia, no date. (From the Company.)
- Western Electric Company, Modern Methods in Train Despatching. New York, no date. (From the Company.)
- Western Society of Engineers, Year Book. Chicago, Ill., 1914. (From the Society.)
- Western Wheeled Scraper Company, six Catalogues. Aurora, Ill., no date. (From the Company.)
- Wetzel Mechanical Stoker Company, Catalogue. Trenton, N. J., no date. (From the Company.)
- George D. Witcomb Company, Mechanical Methods of Mining, Air Hammer Drills. Rochelle, Ill., no date. (From the Company.)
- Wisner Machinery Company. Leaflets on Steam Power Plants, Catalogue of Lanza Portable and Semi-portable Engines. New York, no date. (From the Company.)
- Williamson, R., and Company, Sales Book No. 21, Lighting Fixtures. Chicago, no date. (From the Company.)
- Winter Bros. Company, Catalogue No. 9, Carbon Steel, High-Speed Steel. Wrentham, Mass., no date. (From the Company.)
- Wisconsin Geological and Natural History Survey, Bulletin No. 27, The Inland Lakes of Wisconsin. Madison, Wis., 1914. (From the Director.)
- Henry R. Worthington, Catalogue W 178, Pot Valve Pressure Pumps. New York, N. Y., no date. (From the Company.)
- Yarnall-Waring Company, The Log Book of the Power Plant. Chestnut Hill, Philadelphia, 1914. (From the Company.)

CORRESPONDENCE.

8 SUMMIT STREET, CHESTNUT HILL,
October 5, 1914.

MY DEAR DR. OWENS:

I was so much impressed with the artistic excellence and beauty of the bronze copy of the new Franklin Medal which I saw to-day that I cannot refrain from sending you a note of congratulation upon the acquirement for the Institute of such a valuable addition to the list of awards for important discoveries in science now in the gift of The Franklin Institute.

This medal fills a gap which I have long thought existed, and combines high artistic merit with intrinsic value, making it one which will enhance the reputation of the donor and recipient alike.

I am, yours truly,

(Signed) ALEX. E. OUTERBRIDGE, JR.

BOOK NOTICES.

INTRODUCTION TO ORGANIC CHEMISTRY, by John Tappan Stoddard. Philadelphia, P. Blakiston's Son & Co., 1914. 408 pages, illustrations, 12mo. Price, \$1.50 net.

This book contains a large amount of information in a compact form. It is intended, as stated in the preface, to be used in connection with lectures and laboratory work. It will probably be of much use in the preparation of students intending to enter professional schools, for which an elementary knowledge of organic chemistry is required. The subject-matter follows the usual classification, beginning with the Hydrocarbons and passing to the more complex Compounds. A good deal of information is given as to certain practical bearings of Organic Chemistry.

The work is well written and well printed.

HENRY LEFFMANN.

TENNANT AND WARD'S MANUAL OF PHOTOGRAPHIC PROCEDURE. New York, Tennant & Ward, 1911. 6 volumes, 12mo. Price, 25 cents each.

As the publishers have not given these books a general or serial number, nor indicated the authors, we may describe them collectively by the above title. They are paper-covered "brochures" of about three-score pages each, six in number, giving information about flashlight photography, enlargements, development, outdoor work, dark-room manipulation, and home picture-taking. They have evidently been prepared by practical and skilled workers, and will be aids to amateurs in many ways. In the description of the testing of the safety of dark-room lights it would be well to mention that ordinary emulsions are much more sensitive when dry than when thoroughly soaked with developer.

HENRY LEFFMANN.

METALLURGY, by Henry Wysor. Second edition. Easton, Pa., The Chemical Publishing Company, 1914. 391 pages, illustrations, 8vo. Price, \$3.

There are two distinguishing and meritorious features apparent in this text-book:

First.—It is thoroughly well balanced; that is to say, the twenty-nine separate chapters, covering a wide range of subjects, are so evenly proportioned that criticism on the score that the author has unduly elaborated one branch at the expense of another is completely disarmed. This is a common fault in books of this character.

Second.—There is a total absence of redundancy or "padding." Careful examination enables the reviewer to say that there is not a paragraph that could be omitted without loss of continuity or clearness.

It goes without saying that many things have been omitted which the student must know before he can claim the title of "expert," but it is impossible to give many details in a book of less than four hundred pages covering the general principles of metallurgy.

In his preface the author says: "Every teacher knows that his most ardent and painstaking efforts will be futile if he fails to enlist the students' interest—the beginner needs perspective rather than detail, breadth rather than depth, and when given a view of the subject as a whole and shown something of its meaning, his mind will submit more willingly, if not zealously, to abstraction and detail."

As a former teacher the reviewer can fully endorse this statement, and he congratulates the author upon having produced an exceedingly interesting book, holding the attention of the reader from beginning to end.

Moreover, the text is clear, concise, and up to date, modern electrical processes of steel making and electrolytic methods of refining metals are given, and the final paragraph refers to the latest and most curious "spray process" of depositing metallic coatings on wood, glass, or metals, the invention of M. U. Shoop, of Switzerland, in which the covering metal is atomized and shot out of a pistol in the form of a fine spray with great force, forming, it is said, an adhesive covering of uniform thickness. Objects of wood, metal, or glass may be even coated with aluminum in this way, also with steel. Hitherto it has been difficult, if not impossible, to coat any surface with aluminum or with steel.

This book is especially designed for students, but it is worthy of a place in the library of metallurgists and scientists generally.

A. E. OUTERBRIDGE, JR.

THE HALFTONE PROCESS, by Julius Verfasser. Fifth edition, revised and enlarged. 390 pages, 8vo. London. Iliffe & Sons, Ltd.

The use of halftone illustrations in connection with letter-press in books, magazines, and newspapers, and in commercial publications of all kinds, has become so extensive as to bring the production of this class of photo-engravings to the position of a considerable and growing art industry. The method of production is dealt with more or less fully in treatises on the photo-chemical reproductive arts generally, but in view of the importance of

the halftone process a work specifically devoted to this one subject presents a desirable addition to its literature.

The author, Mr. William Gamble, well known as the editor of the monthly publication, *Process Work*, and of the "Process Year Book," writing under a *nom de plume*, deals with his subject from the standpoint of the practical operator almost exclusively, only so much of the theoretical data relating to it being included as is requisite to afford the worker a proper insight into the process. The nature and peculiarities of the halftone negative, the various kinds of cross-line and grain screens used in its production, and the method of applying the screen in the making of the negative, are described in clear and simple terms and copiously illustrated. The same is true regarding all the other appliances required in the process, from the camera to the proofing press, each of these being considered in connection with the arrangement and outfitting of the several workrooms. A chapter devoted to a detailed consideration of the materials required in the process completes the first part of the book and forms virtually a preface to the second.

In Part II the author deals with the chemical operations incident to the halftone process, including the making of the negative, the sensitizing of the metal plate, the printing of the negative on the metal, and the etching of the plate, keeping in view constantly the needs of the everyday worker and affording him full information regarding matters of practical importance.

This present edition of the work is enlarged by a chapter on recent improvements of the product by means of etching machines, another on the details of the three-color halftone process, and one on the production of halftone illustrations by photo-lithography and the offset press.

A short and concise statement regarding the preparation of the copy for reproduction by the halftone process and various mechanical appliances for this purpose completes the work, which, as already indicated, has been thoughtfully prepared to meet the needs of the halftone photo-engraver. Equally careful, however, appears to have been the avoidance of a date mark anywhere in the book, a growing practice in connection with manuals of this character which is strongly to be deprecated.

L. E. LEVY.

PUBLICATIONS RECEIVED.

U. S. War Department: Annual Reports, 1913. Vol. i, The Secretary of War, The Chief of Staff, The Adjutant-General, The Inspector-General, The Judge-Advocate General, The Chief, Quartermaster Corps, The Surgeon-General, The Chief of Ordnance, The Chief Signal Officer, The Chief of Coast Artillery; vol. ii, Report of the Chief of Engineers (without appendices); vol. iii, Reports of Department Commanders—Eastern Department, Central Department, Southern Department, Western Department, Philippine Department, Hawaiian Department, Commanding General, Second Division, Military Academy Superintendent, Military Parks—Chickamauga and Chatta-

nooga, Gettysburg, Shiloh, Vicksburg; vol. iv, Reports of the Chief, Bureau of Insular Affairs, Philippine Commission, Governor of Porto Rico. 4 volumes, illustrations, tables, plates, maps, 8vo. Washington, Government Printing Office, 1914.

Canada, Department of Mines, Mines Branch: The Copper Smelting Industries of Canada, by Alfred W. G. Wilson, Ph.D., Chief of the Metal Mines Division. 184 pages, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1913. Lode Mining in Yukon: an Investigation of Quartz Deposits in the Klondike Division, by T. A. MacLean, M.E. 205 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1914.

Experimental Studies in Electricity and Magnetism, by Francis E. Nipher. 73 pages, illustrations, plates, 8vo. Philadelphia, P. Blakiston's Son & Co., no date. Price, \$1.25.

U. S. Bureau of Mines: Bulletin 83, The Humidity of Mine Air, with Especial Reference to Coal Mines in Illinois, by R. Y. Williams. 69 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1914.

Aëronautical Society of Great Britain: Technical Terms Committee, List of Terms. 2 pages, folio. London, Society, September, 1914.

Explosibility of Grain Dusts: Comparative Investigation by Millers Committee of Buffalo, N. Y., under the direction of Dr. George A. Hulett, Chief Chemist, U. S. Bureau of Mines. A preliminary report by David J. Price and Harold H. Brown. 59 pages, illustrations, 8vo. Pittsburgh, Pa., July, 1914.

Philadelphia Department of Public Works: Annual Report of the Director for the Year Ending December 31, 1913. 48 pages, 8vo. Philadelphia, issued by the city.

Examination of Lubricating Oils, by Thomas B. Stillman, M.Sc., Ph.D., late professor of engineering chemistry in the Stevens Institute of Technology. 125 pages, illustrations, plates, 8vo. Easton, Pa., Chemical Publishing Company, 1914. Price, \$1.25.

Practical Handbook for Beet-Sugar Chemists: Rapid Methods of Technico-chemical Analyses of the Products and By-products and of Material Used in the Manufacture of Beet-Sugar, by Werner Moeller-Krause, sugar chemist. 132 pages, illustrations 8vo. Easton, Pa., Chemical Publishing Company, 1914. Price, \$1.25.

Ogden's Steam Separator. ANON. (*Mech. Eng.*, xxxiii, 403.)
—In this apparatus for separating steam from water and oil the steam is passed through small curved tubes in a casing; the outer circumference of the tubes is perforated with several holes with their edges bent in oppositely to the direction of motion of the fluid, so that the oil and water projected centrifugally from the steam are passed out into the casing, the steam passing on alone into the delivery pipe to which the separator is connected. Two forms of the apparatus are illustrated.

CURRENT TOPICS

Electro-deposition of Nickel. C. W. BENNETT, H. C. KENNY, and R. P. DUGLISS. (*Journ. Phys. Chem.*, xviii, 373.)—Calhane and Gammage, in their investigations of the electro-deposition of nickel from a solution of nickel-ammonium sulphate, using commercial nickel anodes, found that the current efficiency was greater with stationary than with rotating cathodes, while the amount of iron deposited as impurity increased when the cathode was rotated. The authors have confirmed these results, and, in the light of further experiments, give a satisfactory explanation of them as follows: From the solution of nickel-ammonium sulphate, which is neutral or slightly acid, hydrogen will be deposited first on the cathode. The solution in the neighborhood of the cathode consequently becomes alkaline, and then, and only then, can nickel be deposited. Thus the efficiency of the deposition of nickel depends on the maintenance of an alkaline cathode film; stirring the electrolyte removes this alkaline film more or less completely, depending on the efficiency of the stirring, and thus the current efficiency diminishes. It was further shown that the efficiency can be started high and maintained high by adding a definite amount of ammonium hydroxide to the solution. The fact that the iron content of a deposit formed on a rotating cathode is greater than that formed on a stationary electrode is probably due to mechanical occlusion of the precipitated iron hydroxide from the alkaline solution. The iron content of the anode does not materially affect the efficiency.

Electrical Transmission of Power on Diesel-motor Ships. A. RASMUSSEN. (*Elektrotechn. Zeitschr.*, xxxv, 468.)—Refers to methods by which subsidiary apparatus, such as capstans, are worked by electrical power. The main question refers to the suitable regulation of such auxiliary motors, and the author notices three methods. All the machinery is considered to be operated by series motors, and the first method consists in inserting a resistance in the magnet circuit, so that with a nearly constant current and torque it is possible to allow of heavy loads without blowing fuses, the motor under these conditions being merely brought to rest. The second method puts a resistance in parallel with the magnets, which avoids obvious difficulties that might arise from the heavy currents carried by the windings. The third and simplest plan consists in displacing the brushes, which works well if the currents are not too heavy. The case of the Diesel ship *Seelandia* is taken as a case in point, and figures are given relating to the suggested application of the author's system on board that ship.

Inflammability of Mixtures of Methane and Various Gases. LEPRINCE-RINGUET. (*Comptes Rendus*, clviii, 1999.)—The upper and lower limits of inflammability were determined for mixtures containing methane and oxygen in the constant proportions, $\text{CH}_4 + 2\text{O}_2$, and also varying amounts of nitrogen, carbon dioxide, and water vapor. The effect of added nitrogen was to lower the upper and raise the lower limit until the two coincided at a point corresponding to the composition: $(\text{CH}_4 + 2\text{O}_2)$ 20.1 per cent. and N 79.9 per cent. The effect of carbon dioxide was similar, but of different magnitude, 0.56 volume of carbon dioxide having an effect approximately equal to that of 1 volume of nitrogen. The effect of water vapor could also be represented in a similar manner, so that if the mixture, temperature, and humidity are known, all necessary facts as to the inflammability can be deduced from a single diagram.

Automatic Mercury Pump. KLEIN. (*Journ. de Physique*, iv, Ser. 5, 293.)—This pump differs from older ones of the same type in that the gases, instead of being evacuated directly into the atmosphere, are passed into a canal system connected with a column of water, and, instead of the displacements of the mercury being produced by displacements of the receiver, they are produced by the receiver being put in communication automatically alternately with the atmosphere and with the column of water by a suitable arrangement. Diagrams are given showing the connections of the parts; and the method of working, together with the rate at which the gases are removed, is dealt with in detail.

Principle of Similitude. R. C. TOLMAN. (*Phys. Rev.*, iii, Ser. ii, 244.)—Presents some considerations which appear to have validity throughout the field of physical science. These conclusions are drawn from a single postulate or new principle, which may be stated as follows: The fundamental entities out of which the physical universe is constructed are of such a nature that from them a miniature universe could be constructed exactly similar in every respect to the present universe. This is called the *principle of similitude*.

The fundamental postulate is a relativity principle, *viz.*, the principle of relativity of size. In the body of the paper it is shown that relations must hold between the changes of lengths, masses, time intervals, energy quantities, etc., in order to construct the miniature world in question.

Potash Salts in Spain. (*Board of Trade J.*, July 9, 1914.)—Extensive deposits of potassium sulphate and carbonate have been discovered near Condona, 40 miles northwest of Barcelona. The deposits are of great thickness and begin about 200 feet below the surface.

Electrical Steering of Vessels. H. L. HIBBARD. (*Amer. Inst. Elec. Engin. Proc.*, xxxiii, 703.)—The modern steam steering gear is briefly described; among its disadvantages the author mentions: (1) Long lengths of steam piping and lagging, and rises in temperature of spaces through which the piping passes. (2) Wastage of steam, as steam steering gear takes full stroke, and the valve setting is often such that steam is always blowing through the engine. (3) The engine must be designed for the maximum work required of it,—i.e., when the rudder is at the maximum angle. (4) Severe stresses on reciprocating parts due to sudden decrease of load when the rudder returns to the central position. Mechanical connections from the bridge to the engine valve are a continual source of trouble.

Against these the advantages of the electrical drive are: (1) Reduction of weight and space occupied by driving mechanism. (2) Suppression of heat in compartments. (3) Elimination of accidents due to burst steam pipes. (4) Reduction of vibration and noise. (5) More efficient mechanism, and the overload capacity of the motor can be used in extreme positions of the rudder. (6) Simplification of the control from the bridge. (7) Increase in rapidity and accuracy of response of the rudder to movements of the controlling mechanism.

A short description is given of the early electric gears, and a full description of the recent equipments put into United States battleships, including special contractors for the automatic control of the motor. The method is given for calculating the horse-power required to be installed.

Paper Pulp in the United States. V. E. NUNEZ. (*Papierfab.*, xii, Festheft, 41.)—The sources of supply for paper pulp are diminishing so rapidly that new sources must be sought for. In ten years, from 1900 to 1909, the consumption of pulp-wood in the United States increased by 100 per cent., the increase in home-grown spruce being 35 per cent. and in imported spruce 162 per cent. At present only one-third of the pulp-wood consumed in the United States is home-grown, and the present supplies in this country will probably be exhausted in thirty years. On the other hand, much progress has been made in the utilization of other species of wood which have hitherto been considered inferior for pulp-making. Balsam fir has been found to be a fairly satisfactory substitute for spruce in the manufacture of mechanical pulp for newspaper, while jack-pine and hemlock yield lower-grade mechanical pulp suitable for cheap qualities. Tests are being made with several other varieties of wood available in large quantities in the Western States. The inferior woods are preferably ground in admixture with spruce; fir wood tends to give a free coarse pulp of inferior color to that of spruce; the yield per cord is less, owing to the density of the wood. In the south progress has been made in the utilization of lumber waste, chiefly from long-leaf pine, for the manufacture

of a kraft-cellulose by the sulphate process. It is estimated that sufficient of this waste is available for the production of 10,000 tons of paper per day. There is also a large supply of stumps of black gum wood (*Nyssa sylvatica*), which yields a short-fibred pulp of the poplar class. Large amounts of Douglas fir are still untouched on the Pacific slope in the north. Of the minor sources of supply of paper-making material, sugar-cane refuse, previously shredded and largely freed from "pith" by the Simmons process, is considered the most promising. Fibrous waste from the sisal plantations of Yucatan is also available in substantial quantities, and yields paper pulp of excellent quality. Cotton-seed, hull fibres, and flax straw are capable of development in their respective classes. Corn (maize) stalks, sawgrass, cotton stalks, and many other plants are under investigation, but do not promise so well as the materials previously mentioned.

Production of Explosives in the United States during 1912. A. H. FAY. (*U. S. Bureau of Mines, Technical Paper 69.*)—The total production of explosives in the United States during 1912, according to the figures compiled, was 489,393,131 pounds, or 244,696 short tons. This product is divided as follows: Black powder, 230,233,369 pounds; "high" explosives (dynamite, nitroglycerin, dynalite, gun-cotton, etc.) other than permissible explosives, 234,469,492 pounds; and permissible explosives, 24,630,270 pounds. The total production is tabulated by States, and by kinds of explosives. Another table shows the total output of coal, with the corresponding amount of explosives used in its production. The amount of coal produced per pound of explosive varied from 0.86 ton in the group represented by Arkansas, Oklahoma, and Texas to 5.82 tons in Maryland and Virginia. One hundred and thirty-three men were killed in coal mines by explosives during 1912, and 134 in 1911. In 1902 the quantity of 11,300 pounds of permissible explosives was used in coal mining, whereas in 1912 the quantity so used was 18,150,618 pounds. The total amount of explosives used for the production of coal in 1912 was 226,142,043 pounds. The use of permissible explosives in coal mining has had gratifying results, and few, if any, serious accidents can be attributed directly to their use. In 1912 about three-fourths of the permissible explosives manufactured were used for coal mining. The reports of manufacturers of fireworks and ammunition are not included.

Pitchblende Discovery in India. (*Morning Post*, July 4, 1914.)—Deposits of pitchblende have been discovered in a pegmatite to the east of Banekhap, in the Gaya district of Bihar. At present between 8 and 9 hundredweight have been raised. Samples contained 83.39 per cent. of U_3O_8 , and 260 to 315 milligrammes of hydrated radium bromide per metric ton.

Application of Producer Gas to Brass Foundries. E. F. BULMAHN. (*Trans. Amer. Inst. of Metals*, vii, 288.)—The use of producer gas for melting brass, for drying cores, and for power purposes in the brass foundry is advocated. It is essential that the gas be free from tar. At the Langsenkamp-Wheeler Brass Works, Indiana, an installation of four Westinghouse double-zone suction producers, each having a capacity of 500 pounds coal per hour, has been in operation for four years with satisfactory results. In the double-zone producer the raw fuel (bituminous coal) is carbonized in the upper section, and the residual incandescent coke converted into gas in the lower section. The gas is drawn off between the two sections and serves to generate steam in a vaporizer arranged around the top of the lower section: it is free from tar and is ready for use after passing through a wet coke scrubber and a dry scrubber. The gas has a calorific value of 110 to 115 B.T.U. per cubic foot, and in order to obtain the required temperature in the furnace, 2500° to 2600° F., or 1370° to 1430° C., both the gas and air are preheated by the waste gases from the furnace. Curves are given showing the relative cost of producer gas compared with ordinary lighting gas and with oil fuel. In melting red brass with producer gas the loss of metal was reduced to 0.75 to 1 per cent.

Tungsten in Bolivia. G. W. WEPFER. (*Eng. and Min. J.*, xcvi, 1251.)—Approximately 90 deposits of tungsten ores are known at present, the most important of which are situated in the departments of La Paz and Potosi. Exports were estimated at \$89,932 in 1911 and \$114,847 in 1912. The crushed ore is concentrated on tables. Wolfram concentrates containing tin are calcined and treated by magnetic separation. Sometimes silver occurs in the tungsten or tin ores.

Definition of Adulterated or Loaded Leather. UNION OF SOUTH AFRICA. (*Board of Trade J.*, July 2, 1914.)—The definition of "adulterated or loaded leather" has been revised and now reads as follows: "Adulterated or loaded leather" shall mean leather (other than chrome or other mineral and combination leathers) that contains more than 3 per cent. of mineral ash, or more than 2 per cent. of glucoses and dextrinoids, or any organic matters, other pure tannins, fats, oils, wax and stearine, that are essential to the manufacture of leather. Chrome and other mineral and combination leathers shall not, however, have added thereto, or be loaded with, barium, lead or tin compounds, or magnesium sulphate or sodium sulphate."



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WING DATA AND ANALYSIS FOR A STAGGERED
BIPLANE.*

BY

A. F. ZAHM, M.E., Ph.D.

PART I.—GENERAL DISCUSSION.

IN the JOURNAL OF THE FRANKLIN INSTITUTE for June, 1913, the present writer analyzed the chief stresses sustained by the wing framing of a common orthogonal¹ biplane in straight and in curvilinear flight. The method there developed was applied to a standard Wright and a standard Curtis biplane of that period. To supplement that treatment we may suppose that the planes are staggered, that the spars are continuous from body to wing tip, and that the angle of incidence varies with the speed, thus causing the line of resultant lift to travel. The analysis may be made more complete and more serviceable to the designing draughtsman or engineer by finding the actual distribution of the loads and stresses in a staggered wing during flight at its highest and lowest speeds and angles of incidence. The basic data may be taken from present-day practice.

* Communicated by the Author.

¹ An orthogonal biplane is one whose upper plane is, in normal flight, directly over the lower plane. A staggered biplane has its upper plane placed somewhat forward or aft of the lower one. The first kind has its struts approximately vertical; the second has its struts sloping forward or backward.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

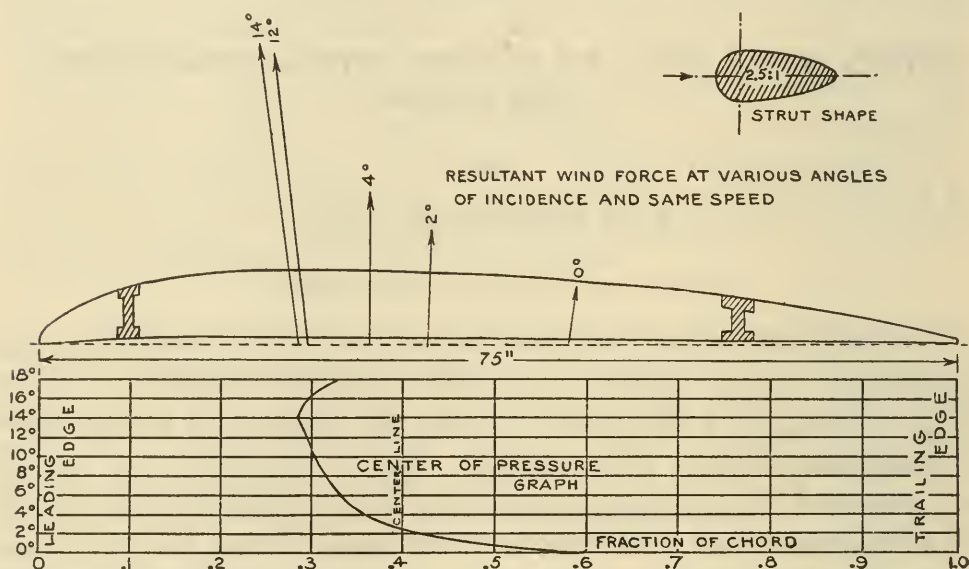
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Given Dimensions.—We may assume that the planes of the wing are parallel, of the same size and shape, the upper one placed 40 per cent. of the gap ahead of the lower. Numerically let us assume the length from fuselage to wing tip 231 inches; the chord length and gap each 75 inches; the section contour as shown in Fig. 1, and known in England as the Royal Air Craft shape No. 6, or R.A.F. 6; the whole length of each plane from tip to tip 41 feet; the whole weight of each plane 129 pounds; the whole weight of machine and load 2190 pounds. These figures are taken from the specifications of an actual biplane.

FIG. 1.



Sections of wing and strut shapes. Wind force on wing planes, in magnitude and position, for various incidences.

Aërodynamic Data.—The resultant wind force on a monoplane wing of the foregoing shape is completely determined by the data of Table I, obtained from wind-tunnel measurements made at the British National Physical Laboratory² for the conditions assigned in the table. From these data the resultant wind force for various angles of incidence is plotted in Fig. 1; also the lift and the ratio life/drift are plotted in the diagram of Fig. 2. The wind forces at any other speed are to these in proportion to the square of the speed of the wing relatively to the air. For a biplane of the same area the wind force is 82 per cent. as much, if there

² See report for 1912-13 of the British Advisory Committee for Aëronautics.

TABLE I.—Characteristic Data for Monoplane Wing Shape. Air at 15° C.—760 mm. Aspect Ratio 6/1. Average Lift of Staggered Biplane Equals 87 per cent. of Tabulated Values.

Angle of incidence.....	0°	2°	3°	4°	5°	6°	8°	10°	12°	14°	16°	18°
Lift in pounds per square foot at 60 feet per second.....				2.419	2.819	3.166		4.328	4.886	5.099	5.061	4.919
Lift to drift ratio.....	.993	1.911	2.195	17.1	16.5	15.6	3.752	12.5	11.5	9.7	7.5	4.3
Centre of pressure in per cent. of chord depth....	8.5	16.3	17.6	.358	.....	.329	14.2	.302	.292	.280	.295	.330
	.375	.425	.....				.312					

TABLE II.—Assembled Dimensions and Computed Values.

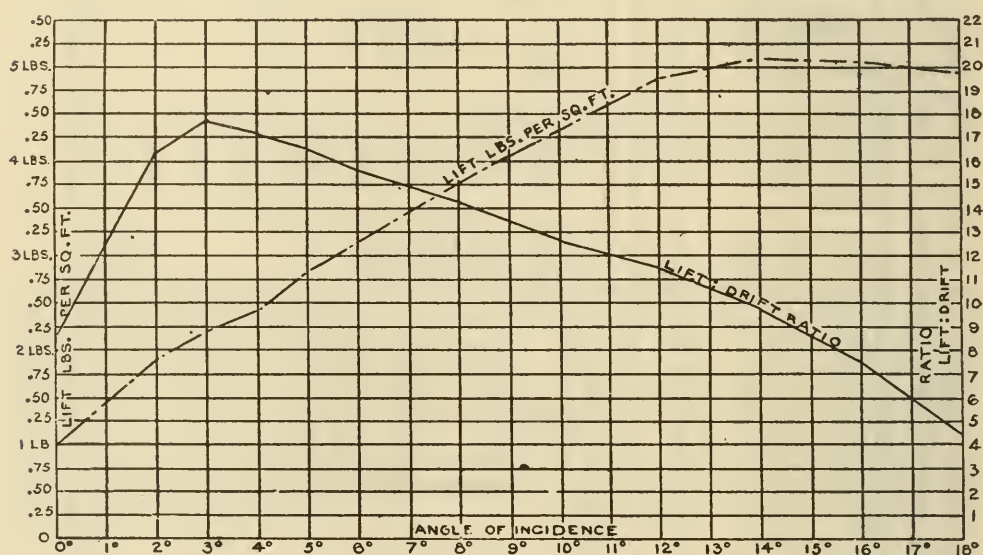
Symbol	Member	Material	Sectional Area	Moment of inertia	Section modulus	At low speed and ∠ of incidence of 12°				At high speed and ∠ of incidence of 0.5°			
						Bending moment	Lift stress	Drift stress	Factor of safety	Bending moment	Lift stress	Drift stress	Factor of safety
A	Front spar....	Spruce.....	4.02	8.18	3.85	1434.8	387.87	0.	13	597.1	172.1	0.	30
B	Front spar....	Spruce.....	4.02	8.18	3.85	1434.8	1058.3	-148.3	10	597.1	469.8	-260.2	16
C	Front spar....	Spruce.....	4.02	8.18	3.85	1434.8	0.	0.	19	488.5	0.	0.	47
D	Front spar....	Spruce.....	4.02	8.18	3.85	1434.8	-387.9	-121.3	33	488.5	-172.1	-212.9	27
E	Rear spar....	Spruce.....	5.26	5.41	3.57	478.3	120.3	148.3	32	1194.3	344.2	260.2	13
F	Rear spar....	Spruce.....	5.26	5.41	3.57	478.3	352.8	247.56	24	1194.3	939.7	434.2	10
G	Rear spar....	Spruce.....	5.26	5.41	3.57	478.3	0.	121.3	45	977	0.	212.2	17
H	Rear spar....	Spruce.....	5.26	5.41	3.57	391.3	129.3	202.3	48	977	-344.2	355.3	21
I	Lift strut....	Spruce.....	.....	0.416	3.57	.....	135.6	.....	7	.....	60.2	.....	16
J	Lift strut....	Spruce.....	.....	0.416	.....	.....	452.4	.....	7	.....	201	.....	17
K	Lift strut....	Spruce.....	.....	0.416	.....	.....	45.2	.....	22	.....	120.4	.....	8
L	Lift strut....	Spruce.....	.....	1.41	.....	.....	150.8	.....	22	.....	402	.....	8
M	Lift cables....	Soft Roebling steel.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
N	Lift cables....	Soft Roebling steel.....	.....	.....	.....	.....	490.7	.....	.....	.....	218.2	.....	.....
O	Lift cables....	Soft Roebling steel.....	.....	.....	.....	.....	925.4	.....	.....	.....	421.2	.....	.....
P	Lift cables....	Soft Roebling steel.....	.....	.....	.....	.....	163.6	.....	.....	.....	436.1	.....	.....
			.....	.....	.....	.....	308.4	.....	.....	.....	822.3	.....	.....

REMARKS: Factors of safety are given for points of greatest fibre stress. For stresses in drift wires and struts see drift diagrams.

be no stagger, and 87 per cent. as much with a 40 per cent. stagger; also the upper plane lifts about 10 per cent. more than the lower one. For want of more exact information, we shall assume the line of the resultant wind force on each plane to be as given by Table I and illustrated in Figs. 3 and 4.

Gross Loading and Limiting Angles of Incidence.—Since the upper plane lifts 10 per cent. more than the under one, we can assume them to bear, respectively, 55 and 45 per cent. of the whole load,—that is, $4190 \times .55 = 1204.5$ pounds, and $4100 \times .45 = 985.5$ pounds, respectively. If the limiting speeds of the aëroplane are to be about 40 and 80 miles an hour, the corresponding angles

FIG 2.



Aërodynamic data and diagram for wind force on wing plane.

of incidence are found by aid of Table I to be respectively 12° and 0.5° . Thus at 12° incidence and 50 feet a second, or about 40 miles an hour, the tabulated lift, multiplied by 87 per cent., is 4.25 pounds per square foot, and this, multiplied by the given wing area, equals the gross weight of the aëroplane; similarly for 80 miles an hour and 0.5° incidence.

Figs. 3 and 4 show the whole wind lift and drift on the supporting planes at the limiting angles, the drift equalling the known lift multiplied by the lift/drift ratio given in Table I and plotted in the diagram. The whole lift and the whole wind force, or resultant of lift and drift, differ from each other by less than half a per cent. for all angles from 0.5° to 12° . This can easily be

shown, since for all these angles the drift is not more than one-tenth of the lift. Thus if the lift be 1, and the drift 0.1, their resultant is $\sqrt{1^2 + 0.1^2} = 1.005$.

Spacing of the Wing Spars.—Fig. 1 shows that, as the wing incidence varies throughout its assumed range of 0.5° to 12° , the "centre of pressure" moves fore or aft through about one-fourth the chord. Hence, if the spars be placed too near together, each in turn may have to sustain the whole load. The farther apart they are spaced the less their portion of the load varies. In the wing under consideration the spars can be placed 48 inches apart and yet have sufficient depth within the canvas. Accordingly the front spar is placed 9 inches from the leading edge of the plane, and the rear spar 18 inches from the trailing edge. The shape and positioning of the spars are as shown in the figure. With this spacing the front spar bears three-fourths of the wind force at 12° and one-half at 0.5° .

Running Loads.—The left-hand diagrams of Figs. 3 and 4 show the running loads on the individual sustaining planes, expressed in pounds of resultant force of wind and gravity on each running inch of the wing length. Thus the resultant or net vertical running lift of wind and gravity on the upper plane equals $(L - W)/l = (1204.5 - 129)/492 = 2.186$ pounds per inch, in which L is the gross lift on the plane, W is its weight, l its length in inches. The net running drift at 0.5° and 12° equals the gross running lift divided by the lift/drift ratio for those angles. At both angles the gross running lift equals $1204.5 \div 492 = 2.45$, very nearly. Hence at 0.5° the net running drift equals $2.45/10.375 = 0.236$, and at 12° it equals $2.45/11.5 = 0.213$, the divisors being the lift/drift ratios for 0.5° and 12° , respectively. In finding this net drift the wind force on the plane alone has been taken, that on the struts and wires being ignored for the present.

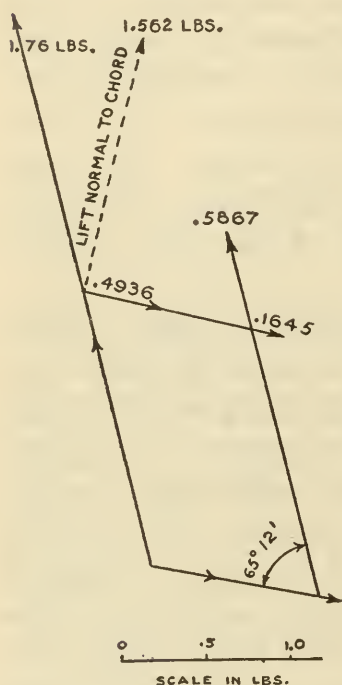
For simplicity the running load is assumed to be uniform from tip to tip of the wings. In reality there is some 10 per cent. decline of running load at the wing ends, and an increase at mid-wing due to the propeller stream. These and many other details must be comprised in a minute wing analysis.

Since, as already explained, the front spar bears three-fourths of the wind force at 12° and one third at 0.5° , it bears at these angles running lifts of $2.186 \times \frac{3}{4} = 1.64$, and $2.186 \times \frac{1}{3} = 0.729$, and running drifts of $.213 \times \frac{3}{4} = .160$, and $.236 \times \frac{1}{3} = .079$; and

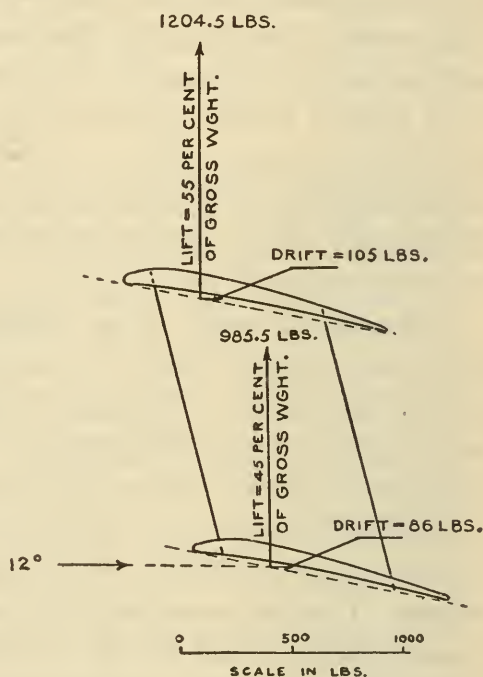
similarly for the rear spars at those incidences. The running loads on the lower spars are $45/55 = 9/11$ of those on the corresponding upper spars.

These running loads have been graphically resolved, as shown in Figs. 3 and 4, in the plane of the front struts and in the plane of the top spars, to obtain the running loads in those planes, and thence the tensions and compressions borne by the truss members

FIG. 3.



NET RUNNING LIFT IN PLANE OF I BEAM WEB
AND
NET RUNNING LIFT AND DRIFT COMPONENTS
IN PLANES OF WING TRUSSING.



WHOLE LIFT AND DRIFT
ON SUPPORTING PLANES.

Whole lift and drift on wing planes at 12° incidence. Running lift and drift resolved in truss planes.

in those planes. Likewise they have been resolved in the plane of the spar web in order to find the bending moment on the spar due to the net running load on it.

Spacing of the Struts along the Spars.—The distances between the struts along the wing may be so chosen as to make the bending moment in any spar the same at all its strut joints. Thus the overhanging wing end is a uniformly loaded cantilever beam whose bending moment next the strut is $wl/12$, if w be the known running load on the spar, and l the length of the overhang. The

next span is a uniformly loaded beam with fixed ends, and next to each strut has the bending moment $wl_2^2/12$, l_2 being its length. The next span is a uniformly loaded beam fixed next to the strut and pinned at the engine section; and next to the strut has the bending moment $wl_3^2/8$, l_3 being its length. Now, since these three moments all are to be equal,

$$\frac{wl_1^2}{2} = \frac{wl_2^2}{12} = \frac{wl_3^2}{8}$$

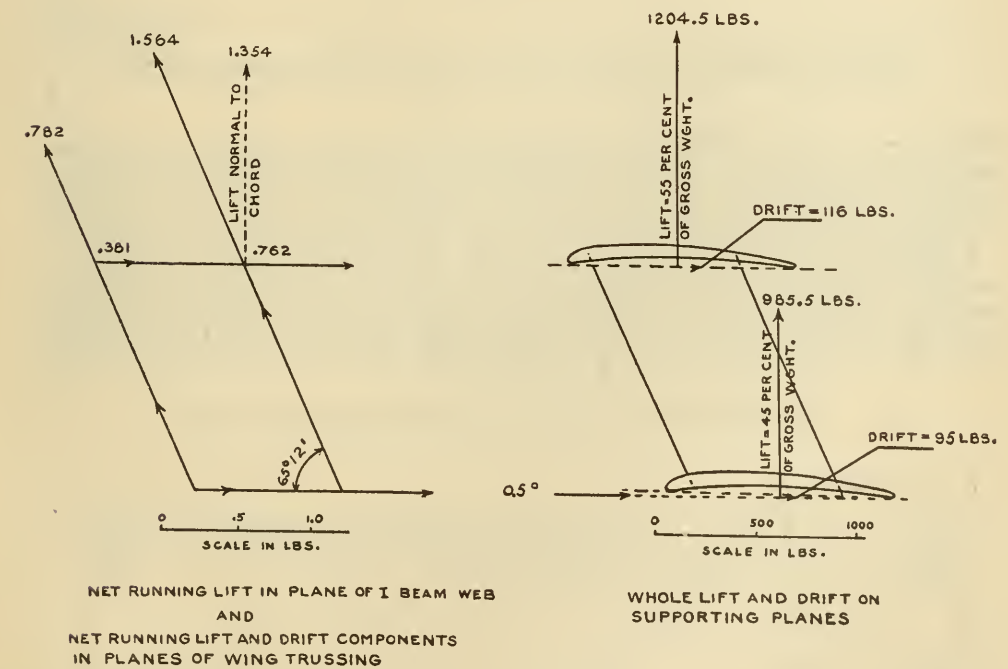
Also, since the sum of the span lengths equals the given wing length,

$$l_1 + l_2 + l_3 = l$$

Solving these equations, we find

$$l_1 = .1855\ l; \ l_2 = .4535\ l; \ l_3 = .5710\ l \dots\dots\dots (A)$$

FIG. 4.



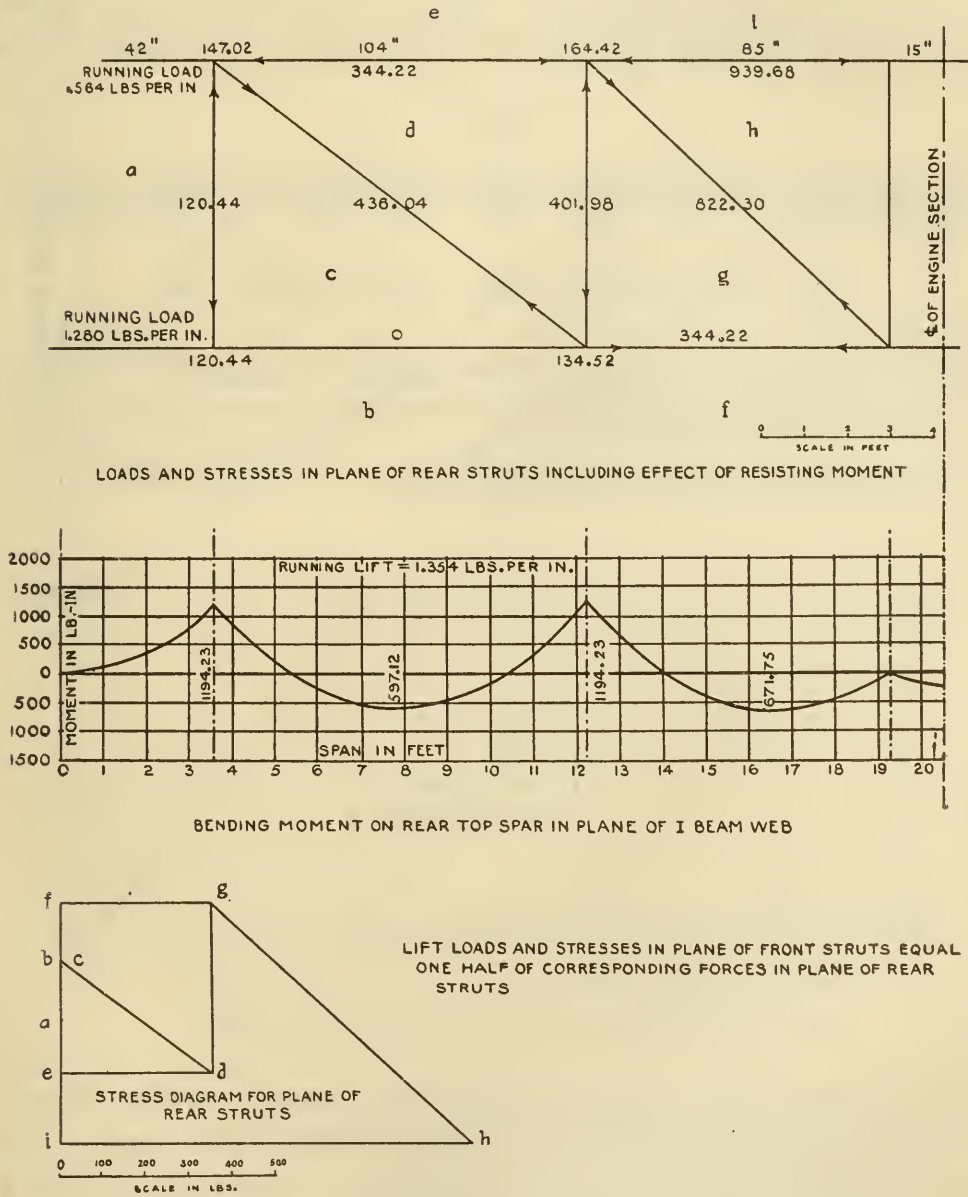
Whole lift and drift on wing planes at 0.5° incidence. Running lift and drift resolved in truss planes.

In the actual aëroplane under discussion $l = 231$ inches; hence $l_1 = 42.42$, $l_2 = 103.8$, $l_3 = 84.8$, are the lengths of span required to make equal bending moments in the spars at the strut joints. Actually the spans were made 42 inches, 104 inches, 85 inches in length.

A more general method of finding the bending moments in a
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ments, tensions, and compressions, which are now to be found. The fore-and-aft diagonal wires, having no external hold, can offer no resistance to the wind lift and drift, but only to a change of parallelism of the spars. The wind lift and drift are borne

FIG. 6.

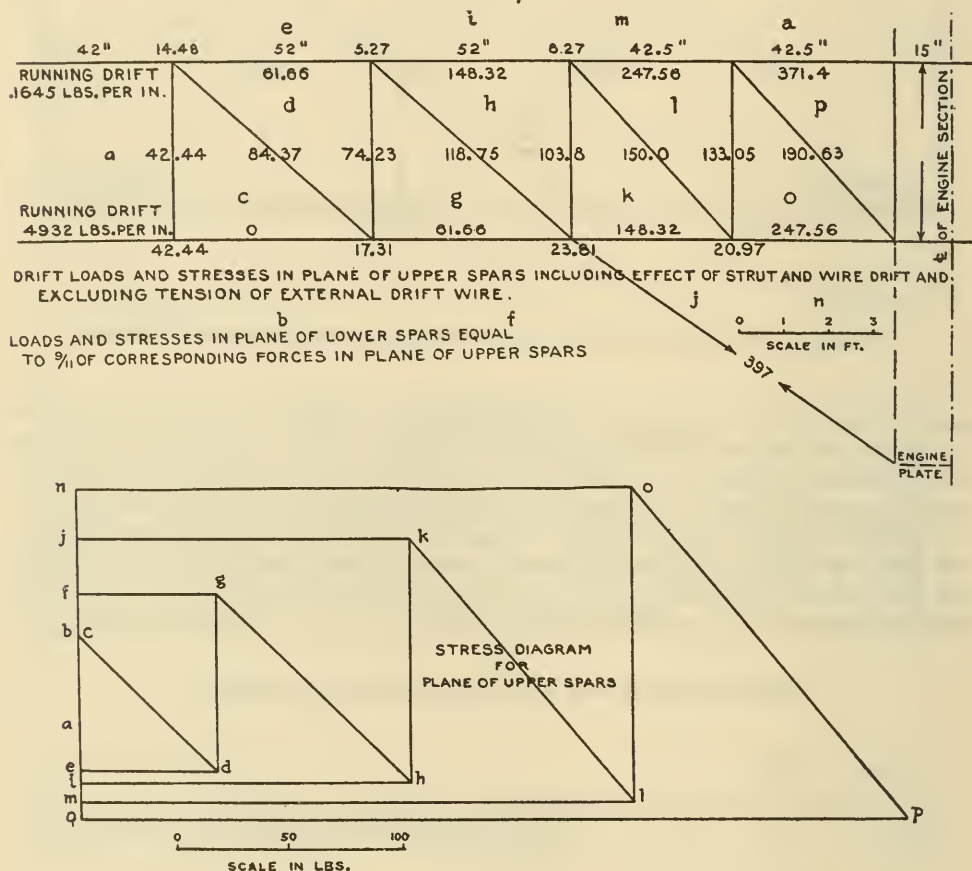


Frame, stress, and moment diagram for plane of rear struts at 0.5° incidence.

by the trussing in the four geometric planes containing, respectively, the front posts, the rear posts, the upper spars, the lower spars. We may now analyze the forces and reactions in these four planes. The stresses are written in pounds, the moments in pound-inches.

Applied Forces and Reactions in the Planes of the Struts.—The trussing in the plane of the front spars and struts, together with the applied forces and reactions at 12° incidence, is shown in Fig. 5. The upper part of the figure shows the distribution of the loads, as derived from Fig. 3, and the resulting endwise stresses in the struts, stays, and spars. The middle of the figure shows the bending moment diagram for the upper front spar. The

FIG. 7.

Frame and stress diagram for upper plane at 12° incidence.

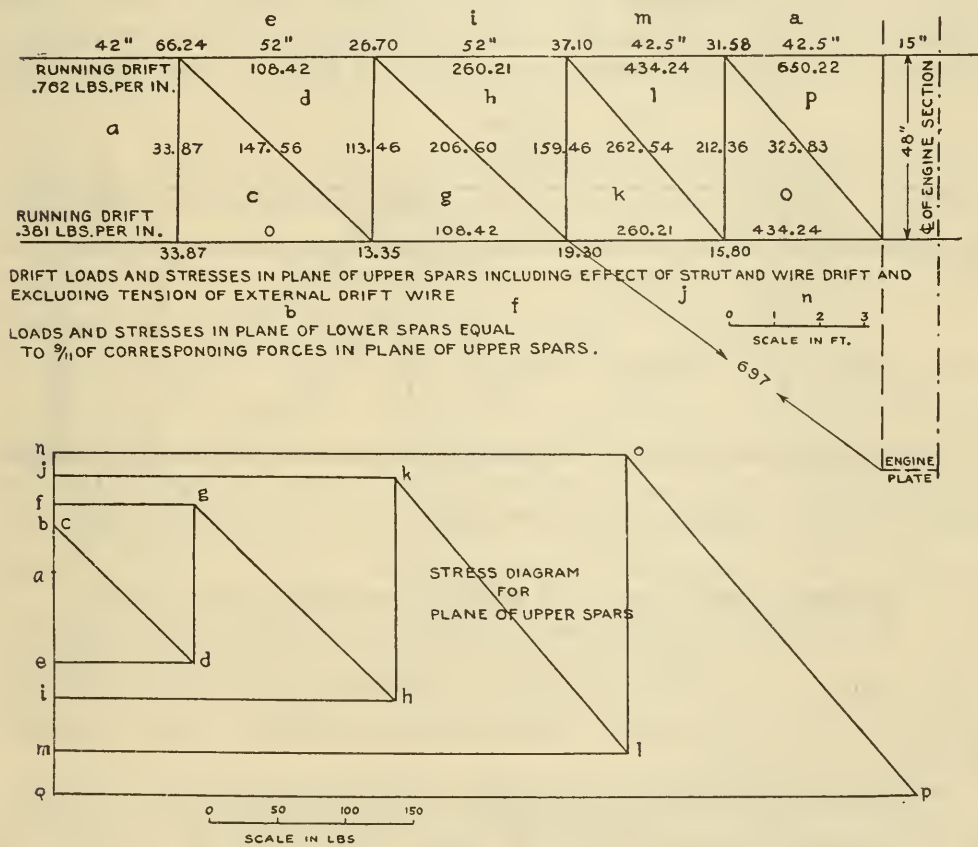
bottom of the figure presents the stress diagram, giving the tensions and compressions in all the truss members in the plane. The analytical determination of these reactions is explained in Part II of this article; the graphical analysis needs no explanation. The stays omitted from the frame diagram sustain in flight no stress due to the wind force unless this be exerted on top of the planes, as when a sudden downward puff occurs.

From the three diagrams in Fig. 5 like ones for the other

geometric planes and for the same incidence can be sketched by simple comparison. Thus the loads and reactions in the plane of the rear struts equal one-third of those in the diagram for the corresponding forces in the plane of the front struts; the bending moment acting on either bottom spar is 9/11 of that in the spar above it.

Fig. 6 is a repetition, made for 0.5° incidence, of Fig. 5, except

FIG. 8.



Frame and stress diagram for upper p'lane at 0.5° incidence.

that now the trussing of the rear posts and spars is represented. The loads and reactions in the plane of the front posts are one-half those given in the diagram of Fig. 5, and the bending moment in either bottom spar is 9/11 that in the spar above it.

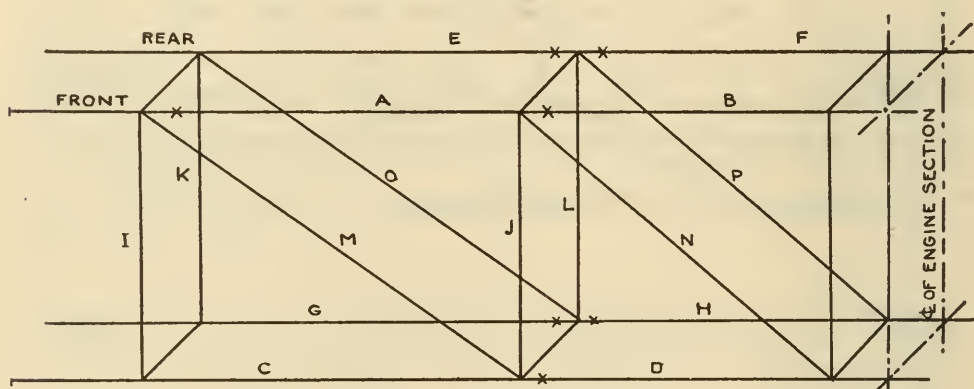
Applied Forces and Stresses in the Upper and Lower Planes.—The trussing in the plane of the upper spars, together with the applied forces and stresses at 12° incidence, is shown in Fig. 7. The upper diagram of the figure gives the distribution of loads for that plane, as derived from Fig. 3; also the endwise stresses

in the "drift" struts and stays and in the spars. The bending moments in the spars in this case are ignored as insignificant. The bottom of the figure presents the stress diagram for the upper plane in question.

Fig. 8 is a repetition, made for 0.5° incidence of Fig. 7, and requires no special explanation.

Particular attention may be directed to the great magnitude of the compressive stress, 650 pounds, in the upper rear spar in Fig. 8. This is mainly due to the staggering, and hence to the obliquity of the "lift" stay wires joining the upper and lower planes. As can be shown by analysis of Fig. 4, over five-sixths

FIG. 9.



REFERENCE DIAGRAM—POINTS OF GREATEST FIBRE STRESS MARKED THUS "X"

Conspectus of wing members, with dimensions, stresses, and factors of safety.

of the stress in the drift trussing here shown is due to the obliquity and backward pull of the "lift" stays, and less than one-sixth is due to wind drift.

The stresses in the external drift wires, shown in Figs. 7 and 8, are computed separately, as if these wires had to sustain the entire rearward pull on the wing. The method of computation is given in Part II of this article.

The applied loads and stresses in the lower plane are $9/11$ of the corresponding ones just found for the upper plane.

Assembled Dimensions and Computed Values.—Fig. 9 shows in perspective the wing members which bear the chief fibre stresses, and Table I contains the chief specifications and computed values for those members. The ultimate object of this table is to bring out the factors of safety for the parts of the wing framing subject to the greatest fibre stress. The unit stresses for 12° in-

cidence, derived from columns 4, 6, 7, 8, 9, are algebraically added, then divided into the ultimate strength of the material to obtain the factor of safety tabulated in the tenth column; similarly for the columns which apply to 0.5° incidence.

As an example, let us find from these columns the factor of safety for the spar member B, at the point marked \times . By columns 6 and 7 the unit fibre stress in B, due to the bending moment caused by the running load, is $1434.8 \div 3.85 = 372.7$ pounds per square inch, since the greatest fibre stress at any section of a beam, due to bending, equals the bending moment divided by the section modulus. Again, by columns 4, 8, 9, the unit fibre stress due to B's compressive stress, 1058.3, and B's tensile stress, -148.3, is $(1058.3 - 148.3) \div 4.02 = 226.4$ pounds square inches, the divisor being the cross-sectional area of B in square inches. Finally, the factor of safety is $6000/599.1 = 10$, the numerator being the assumed ultimate strength of spruce, the denominator being the sum of the stresses 372.7 and 226.4, just computed.

In like manner have been derived all the other tabulated factors of safety for the spars. The factors of safety for the cables or stays can be written at once as the quotient of the cable's strength divided by its stress, the strength being given by the manufacturer or testing laboratory. The factor of safety of the struts is found as the quotient of their working stress divided into their ultimate strength as computed by means of Euler's formula for long columns, as explained in Part II of this paper.

PART II.—DETAILED ANALYSIS.

Wing Loads and Stresses Due to Wind Lift at 12° and 0.5° Incidence, Including Effect of Resisting Moment.—From the running loads on the spars shown in Fig. 5, the lift exerted by these spars on the struts joining them is found to have the numerical values marked at the strut joints. The loads and stresses are expressed in pounds.

Thus the bottom of the outer strut sustains all the running load on the lower spar from its outer tip to the centre of the middle span, a distance of $42 + 104/2 = 94$ inches. This lift, therefore, equals $94 \times 1.44 = 135.56$ pounds. Similarly the top of the same strut is lifted with a force of $94 \times 1.76 = 165.44$ pounds. In proof of these statements it may be observed that the middle span, being a uniformly loaded beam with fixed ends, is known to have its

shearing force equal to zero midway between the struts. This means that if the spar were severed at the middle of this span the lift of its 94-inch segment would balance on the strut and hence would exert its whole lift there.

The span next the engine section has its point of no shear at a distance of five-eighths of its length to the right of the strut, or $85 \times \frac{5}{8} = 53.125$ inches. Hence the lift exerted on the bottom of this strut by the lower spar is $(52 + 53.125) 144 = 151.38$ pounds. Similarly the top of the same strut is lifted with a force of $151.3 \times 11/9 = 185.02$ pounds.

Having now the values of all the applied wind lifts concentrated at the joints of the given frame, we can proceed to find the resisting tensions and compressions in the frame members. The values of these stresses, as found from the stress diagram in the bottom of Fig. 5, and checked by computation, are marked in the frame diagram.

A similar analysis applies in the case of 0.5° incidence, as shown in Fig. 6.

Bending Moment on the Spars Due to Wind Lift.—Since the spars are assumed to have a uniform running load, the bending moment at all the points of their length can be found from the well-known properties of familiar types of beams. The moments here found are expressed as pound-inches.

Thus the overhang at the outer end of each plane can be treated as a uniformly loaded cantilever beam, whose maximum bending moment is $wl^2/2$, w being the running load, l the length. Hence for the front top spar just outside the strut the bending moment is $1.76 \times 42^2/2 = 1434.8$ pound-inches. This value is plotted as a positive ordinate in the bending moment diagram in Fig. 5, together with values similarly found for intermediate points on the cantilever. The points lie on the curve—a parabola—to the left of the line of the outer strut.

Again, the bending moment at each end of the mid-span is, by express design, 1434.8, and at its middle is, by the formula for such a beam, minus one-half of 1434.8 = -717.4, pound-inches. By the formula for such a beam, the moment is zero at one-fifth the distance from either end of it, or, more exactly, at $.2113 l$, where l is its length. Thus we have five points on the bending moment curve—a parabola—and easily draw it, as shown in the figure between the two strut positions.

The bending moment for the span next the engine section is 1434.8 at the strut, 0 at the pin joint on the fuselage, 0 at one-fourth its length to the right of the strut, and at $\frac{5}{8}$ of its length is $\frac{9}{16}$ of its greatest value, or $\frac{9}{16} \times 1434.8 = 807.64$ pound-inches.

For corresponding points at 12° incidence, the bending moment on the rear top spar is one-third that on the front one; the moment on the bottom spars is $\frac{9}{11}$ that on the corresponding top spars.

For the case of 0.5° incidence the bending moment diagram, obtained for one of the spars in an analogous way, is shown in Fig. 6, and the diagrams for the remaining spars can be constructed as before by merely changing the scale. Thus at 0.5° incidence the moments on the front spar are one-half those on the rear one; the moments in the bottom spars $\frac{9}{11}$ of those above.

Wing Loads and Stresses Due to Drift at 12° and 0.5° Incidence, Excluding Effect of Resisting Moment but Including Drift on Struts and Stays.—Figs. 7 and 8 show the frame and stress diagrams for the internal trussing of the upper plane. In finding the resultant effect of the running load, considered as applied at the frame joints, no regard is paid to the influence of the stiffness or resisting moment of the beam, since this is slight. In fact, the spar is treated as if pin-jointed at all the various intra-canvas struts and stay connections, excepting at the outer post, where it is considered continuous. The drift of the wind on the struts and wires is assumed to add at each external strut joint a horizontal force of half a pound at low speed and two pounds at high speed. A similar treatment applies to the lower plane.

This premised, the 94 inches length of overhang and first span in Fig. 8 bears a resultant wind drift of $94 \times .4932 = 46.36$ pounds at its middle, or 5 inches from the outer joint, and 47 inches from the next joint; and it exerts upon these joints, respectively, the pressures $46.36 \times \frac{47}{52} = 41.9$, and $46.36 \times \frac{5}{52} = 4.46$. To the first of these must be added half a pound drift for the strut and stay, making 42.4 pounds; and similarly for the corresponding portion of the rear spar.

The aggregate wind drift on each of the other spans is divided into halves, and each of the other inter-canvas struts within the restraining plane is assumed to bear one-half of the wind drift on its two adjoining spars. At each joint where an external strut

joins the spar an extra half pound is added for the wind drift of strut and wire.

In this way were obtained all the external applied forces marked numerically at the joints of the frame diagram. Now, having the dimensions and loads of the frame diagram, the stresses,—that is, tensions and compressions,—in the members of the frame can be found graphically and analytically by the usual procedure in mechanics. The treatment is quite analogous for the higher speed and 0.5° incidence, in which case the strut and stay drift to be added at each strut joint is 2 pounds.

The bending and resisting moments are ignored in Figs. 8 and 9, as being very slight. Also the influence of the external drift wire is ignored in the computation of the frame stresses; then in turn this wire is assumed to bear all the drift on the wing, and its tension is computed on that assumption.

The external drift wire is regarded as the diagonal of a right prism whose horizontal sides, given in the figure, are 85 and 60 inches, and whose vertical side is 60 inches; that is, the diagonal is 115 inches long. Hence the tension in this forward-and-downward-drawn wire must be $115/60$ of the forward pull it exerts on the wing. But, by taking moments about the wing root, this forward pull can be found from the given applied forces to be 209.7 pounds at 12° incidence, and 376 pounds at 0.5° incidence. Hence, finally, the tension in the external drift wire is $209.7 \times 115/60 = 397$ pounds at 12° , and $376 \times 115/60 = 697$ pounds at 0.5° incidence, as given in Figs. 8 and 9.

Sections, Strengths, and Factors of Safety of Spars and Struts.—From the linear dimensions of the beam section shown in Fig. 1 the area, moment of inertia, and section modulus are computed by the methods of elementary mechanics, and tabulated respectively in columns 4, 5, and 6 of Table II. These are used, together with the stress and moment columns, to find the factor of safety, in the manner already explained and illustrated.

The moment of inertia of the mid-sections of the struts, illustrated in Fig. 1, is obtained by comparison with that of a standard strut one inch thick, whose moment of inertia about a fore-and-aft axis is found by piecemeal³ integration to be 0.1138. Thus

³ That is, the section area is divided in small rectangles, and the area of each rectangle is multiplied by the square of its distance from the axis of the section. The sum of the products is the moment of inertia.

the outer strut, which is $1\frac{3}{8}$ inches thick, has the moment of inertia $0.113 \times (1\frac{3}{8})^4 = 0.416$, while the inner strut, which is $1\frac{7}{8}$ inches thick, has the moment of inertia $0.1138 \times (1\frac{7}{8})^4 = 1.41$. Substituting these values in Euler's formula for ultimate strength, $P = \pi^2 EI / l^2$, in which $\pi^2 = 10$, $E = 1,600,000$, $l = \text{strut length} = 80.75$ inches, and I is the moment of inertia of the strut section, there results $P = 1021$ pounds for the outer strut, $P = 3460$ for the inner one. Dividing these strut strengths by the actual compressions they bear, as shown in the stress diagrams and also in Table II, the corresponding factors of safety are obtained.

It gives me pleasure to acknowledge the kind service of Mr. Henry Kleckler and Mr. A. V. Verville in making the computations and drawings included in this paper.

Talc as a Lubricant. F. THALBERG. (*Chem. Zeit.*, xxviii, 711.)—Talc does not behave like graphite on treatment with tannin solutions, but may be brought into a finer molecular state by heating with ammonium carbonate, or by several hours' exposure to a current of dry ammonia. Afterward talc is dried *in vacuo*, since heating causes the particles to agglomerate again. The treated material forms fine suspensions in water which are very difficult to filter, and subsides exceedingly slowly in lubricating oils of medium density. When once suspended in a neutral oil no subsidence of the talc occurs on heating. The change in the character of the talc is attributed to the absorption of a minute quantity of ammonia. From 40 to 60 per cent. of ordinary talc may be introduced into heavy mineral oil, provided that the oil be added to the talc and not the reverse.

Weighting of Silk with Substitutes for Tin. E. STERN. (*Z. Angew. Chem.*, xxvii, 357.)—The earths of monazite sand, as well as titanium and zirconium compounds, could not be used successfully by themselves as substitutes for tin salt, yet satisfactory results can be obtained when used in conjunction with tin. It is suggested that substances analogous in constitution to silk fibroin would be preferable.

Nickel-plated Aluminum. E. TASSILY. (*Rév. Mét.*, xi, 670.)—An adherent nickel deposit on aluminum is easily obtained by Canac's process (English patent 24,019 of 1911). The aluminum is treated with boiling potassium carbonate solution, then brushed with milk of lime, and immersed for a few minutes in a 0.2 per cent. solution of potassium cyanide and in a solution of 1 gramme

of iron in 1 litre of hydrochloric acid (1 : 1) until it acquires a moiré appearance. The nickel is deposited as usual, *e.g.*, from a bath containing 50 grammes of nickel chloride and 20 grammes of boric acid per litre. The addition of iron to the last preparing solution is essential; a minute deposit of iron (0.25 to 0.5 gramme per square metre) was found on the aluminum, and microscopical examination of the surface showed a cellular structure. The iron appears to form a network of microscopic galvanic couples, which produces a rough surface. This accounts for the strong adhesion of the deposit, which can not be detached without also tearing off aluminum particles.

The Manufacture of Electrolytic Alkali. DISCUSSION. (*Soc. Chem. Ind. Journ.*, xxxii, 993.)—This discussion tended to show that several processes were technically satisfactory. The Finlay cell produces 8 per cent. caustic liquor at a voltage not exceeding 3, and with a cathodic current efficiency of 98 to 99 per cent. The Billiter-Siemens cell was also satisfactory. The main point is the price at which power can be purchased or generated. Some speakers thought that the figures obtained by the best municipal authorities represented the irreducible minimum, while others asserted that even a small private plant with 100 per cent. load factor, such as would be the case with an electrolytic alkali plant, could be worked much cheaper, and could generate power at a price of 0.1d. per unit. Particulars were given of working results obtained with cells of the rocking Castner type. The total loss of mercury should be less than 2 per cent. per annum, and profits could be made if power did not cost more than 0.3d. per unit.

Prevention of Cementation by Metallic Deposits. L. GUILLET and V. BERNARD. (*Bull. Soc. d'Encour.*, cxxi, 588.)—A layer of electrolytically deposited copper, 0.02 to 0.04 mm. thick, is stated to be the most advantageous coating agent for protecting portions of an article from cementation. Nickel can not be used instead of copper, as it is permeable to carbon monoxide. *Diffusion of Solid Metals.*—When the following pairs of metals were heated together, with their surfaces in intimate contact to a temperature below the fusion point of the lowest-melting metal, diffusion of one metal into another was observed: Iron-aluminum; iron-copper; copper-nickel; copper-bronze; copper-tin; copper-brass; copper-zinc.

Bactericidal Power of Mercuric Iodide. H. STASSANO and M. GOMPEL. (*Comptes Rendus*, clviii, 1716.)—Comparative experiments with mercuric chloride, iodide, cyanide, and benzoate, carried out with very dilute solutions (N/1000 to N/500,000) in order to avoid the use of double salts, indicate that mercuric iodide is a much more powerful bactericide than the other salts and is about ten times as active as the chloride.

THE ULTRA-VIOLET RAYS AND THEIR APPLICATION FOR THE STERILIZATION OF WATER.*

BY

M. von RECKLINGHAUSEN, Ph.D.,

The R. U. V. Company, Inc., New York, N. Y.

WE have seen within the last years the creation of a new industry,—namely, the application of ultra-violet rays for the biologic purification of water. I think it of interest to lay before you the basis on which this industry is founded.

Almost every source of light produces with the visible rays some wave-lengths shorter than those which are perceptible to our eyes. These radiations are known as ultra-violet rays. They begin at about $.3969\mu$ and have been observed down to wave-lengths of about $.1000\mu$. I may say at this point that some observers have been able to get light sensation from wave-lengths shorter than $.3969\mu$. This, however, is explained by the fact that the crystalline of our eyes becomes fluorescent under the influence of such ultra-violet radiations, and produces thereby the impression of gray on the retina; that is to say, we do not see the ultra-violet light, but we see the fluorescence of our own crystalline.

This production of *fluorescence* is one of the characteristics of ultra-violet radiations. It is very noticeable with many of the fluorescent dyestuffs and organic compounds.

Another physical quality of ultra-violet radiations is their ability to *ionize* the air, which manifests itself by the automatic discharge of a condenser under ultra-violet light.

More distinct are the *chemical reactions* under ultra-violet light, the most noticeable being the generation of ozone and nitrous acid, which produces the characteristic odor of spark and arc discharges. Almost any chemical reaction which is influenced by the presence of light is much more influenced by

*Presented at the meeting of the Section of Physics and Chemistry held Thursday, October 1, 1914.

ultra-violet light. I mention only the decomposition of silver salts.

The typical characteristic of ultra-violet light (which is practically confined to these wave-lengths, with the exclusion of the visible wave-lengths) is the *bactericidal* power or, to use a more general expression, the "abiotic power" of these radiations. That the visible rays have practically no abiotic (but even philobiotic) power is probably due to the fact that living beings have adapted themselves to the rays which they generally receive from the sun, while they are not resistant against rays which they do not normally receive. In the same way they will withstand certain temperatures they are accustomed to, but will suffer from higher temperatures.

As said before, some wave-lengths are favorable to life. I refer to the chlorophyll production for which light is necessary. It may be seen, therefore, that exact information on the favorable or unfavorable influence of light on life can be obtained only by separating the visible from the invisible rays. There is, unfortunately, no source of light known which produces only ultra-violet radiation without producing at the same time visible wave-lengths.

The first work in this line is due to Downs and Blunt, who studied the action of sunlight on different organisms and organic tissues. We owe some further results to Geissler, Chmelewski, Bruckner, Duclaux, Ledoux, and particularly to Marshall Ward, to whom we owe the first biologic spectrum analysis. He threw the spectrum on an infected agar plate, with the result that the parts of the plate which were exposed to the violet end of the spectrum did not show any growth of colonies, while the parts which were exposed to the red end of the spectrum developed growth. He found that the abiotic power of ultra-violet light was the same in air as in vacuum. Ward sterilized Thames water by exposing it to ultra-violet light.

However, we owe to Finsen and his school the first real analysis of the abiotic phenomena occurring under the influence of ultra-violet light. His work resulted in the therapeutic use of the ultra-violet ray lamps. Finsen found that the abiotic reaction became very powerful as soon as one reached wave-lengths shorter than $.3\mu$; that is to say, as soon as wave-lengths

appeared shorter than those contained in the sun's rays on the surface of the globe. Finsen proved that abiotic action was independent of the presence of oxygen. He also studied the powerful absorption of ultra-violet by colloidal solutions. His pupil, Bang, determined the relative resistivities of different germs to this light. He also found that young cultures were less resistant than older ones. Some of Finsen's pupils proposed the adoption of ultra-violet light for the sterilization of liquids such as milk, etc. In short, we may say that since Finsen's time the ground was well prepared for the industrial application of ultra-violet light for the biologic purification of different substances.

These studies were taken up again in 1909, particularly in France, by Courmont, Nogier, Vallet, and others. Very elaborate researches were carried on in the Physiological Laboratory of the Sorbonne University by Henri, Helbronner, and von Recklinghausen, which work has resulted in considerable technical application.

The history of this industrial use of the ultra-violet rays is intimately linked with the development of means for producing these ultra-violet rays. It is therefore of interest to go somewhat deeper in the subject of different sources which produce these rays.

The great source of ultra-violet radiations and "the cheapest disinfectant known," as Duclaux puts it, is the *sun*. Rivers and lakes are freed from a great part of their bacterial contents by the bactericidal power contained in the sun's rays.

The spectrum of the sun is in itself not very rich in ultra-violet rays of short wave-lengths, the shortest being $.29\mu$. However, in high altitudes where the light of the sun has to pierce a smaller layer of air it is much richer in ultra-violet, as may be seen from the fact that sunburns are quickly produced if we expose ourselves in high altitudes—mountains or balloons—to the sun.

Small amounts of ultra-violet are produced by practically all artificial light sources. Electric discharges, and particularly the discharges between volatilizable metals,—that is to say, spark-gaps and arcs between metal electrodes,—are very powerful producers of ultra-violet radiations. Finsen himself used an arc between iron electrodes after having found that such an arc is about fifty times as powerful as an arc of the same wattage be-

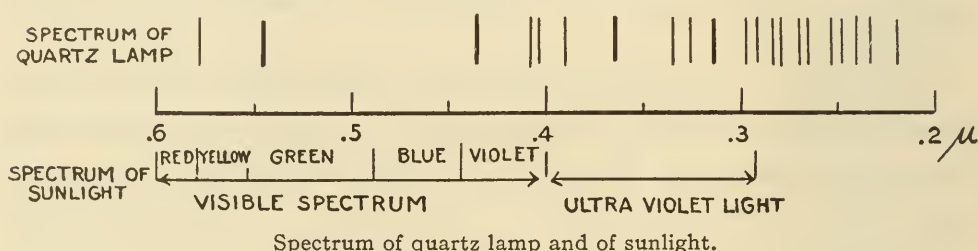
tween carbon electrodes. Electrically speaking, the arcs between metal electrodes are more stable and easier to produce than spark discharges, because the apparatus is simple, as it consists merely of the electrodes and the necessary ballast resistances.

Powerful spark discharges are difficult to produce; the high tension accessories from them are cumbersome and apt to get out of order; besides, all large-capacity sparks have the disagreeable feature of producing a fearful noise, reminding one of a machine gun.

Arcs as well as sparks are accompanied by disintegration of the metal and the production of metal fumes. These have to be removed from the sphere of discharge so as to prevent obturation.

The disintegrated metal has to be replaced after being volatilized by the heat of the arc or spark discharge. The replacement

FIG. 1.



is easiest if the disintegrated metal condenses easily and can be made to flow back to the electrode containers. This is the case if *mercury* is chosen as electrode for the discharge. Means have to be provided to hold the vapors of the disintegrated mercury together and prevent their contact with the air; that is to say, the arc has to be enclosed. The material into which the arc is enclosed has to be transparent to the discharge of ultra-violet rays. The only industrial material filling this demand is rock crystal in the natural or fused state, which we commonly call fused quartz (Fig. 1).

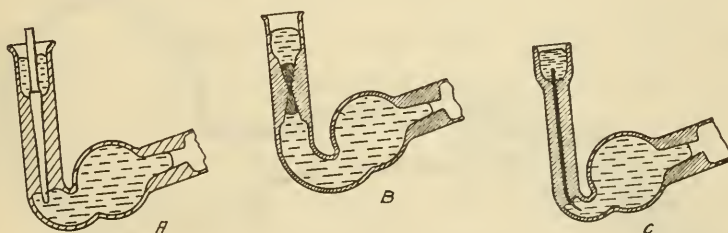
The reason why Finsen's research would not yield immediate technical application was the fact that this mercury quartz lamp did not exist at his time. The mercury arc, although one of the first powerful arcs invented (Way, 1860), became a commercial device only some thirteen years ago, when Cooper-Hewitt's research produced the now well-known Cooper-Hewitt lamp, where the mercury electrodes and the discharge path were enclosed in

glass. Schattner and chiefly Kuech and Heræus, and later on the Westinghouse-Cooper-Hewitt Company, built these lamps out of quartz.

Their reason for using this material in preference to glass was originally not so much on account of the permeability of the quartz for ultra-violet rays, but because the quartz, having a melting point of about 1700° C., allowed them to run the lamps at a greater temperature than glass lamps. Thus the lamps became very much shorter and easier to handle mechanically than the cumbersome glass tubes. As quartz allows, roughly, 1000 times as much of the ultra-violet to pass through as glass, we have, naturally, to use exclusively quartz-enclosed mercury lamps for the industrial production of the desired ultra-violet rays.

The construction of the mercury quartz lamps presents one

FIG. 2.



Quartz lamp seals.

difficulty which we do not have in the case of the glass lamps. In the latter the current is led into the lamp through platinum wires which are fused into the walls of the tube, this being easy to do, as the expansion coefficients of glass and platinum are very much alike, and it is therefore not difficult to render such a platinum glass seal tight. Quartz, however, has an expansion coefficient which is practically zero, and there exists no metal of similar characteristic at the temperature where quartz is soft enough to mould it into a seal. We are therefore unable to produce in this simple way the current leads.

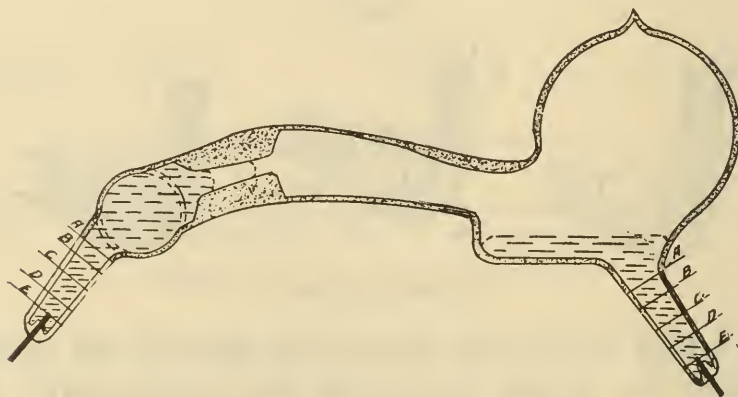
Several ways have been proposed to overcome this difficulty; the first and most commonly used is (Fig. 2A) to grind a stopper into the quartz tube, choosing as material for this, a metal which has as low a temperature coefficient as possible in the range of temperature to which such a seal is normally exposed; that is to say, between room temperature and about 300° C. The metal composition used for this purpose is Guillaume's nickel steel alloy, "In-

var." Its expansion coefficient is practically zero. However, if heated above the temperature of 300°C. , the expansion coefficient becomes highly positive. It is therefore clear that this is one important reason why Invar can not be sealed into quartz at the latter's softening point. After grinding the Invar stopper into the lamp, mercury must be placed on top of the seal so as to prevent the air from leaking into the lamp.

Another way which was used for some time was the double cone seal made of platinum (Fig. 2B), which is fused into a restriction in the quartz tube. This seal also has to be covered with mercury so as to make it air tight.

Some other metals, such as tungsten and molybdenum, can be sealed into quartz (Fig. 2C). In cooling, however, they will

FIG. 3.



110-volt mercury vapor quartz lamp.

contract, and such a seal will leak. This can be prevented by mercury sealing, as described above for the Invar seal.

Keyes and Kraus have made seals for quartz lamps (Fig. 3) by using an ordinary platinum glass seal which was fastened to the quartz tube *A* by means of several intermediate steps, *B*, *C*, *D*, *E*, of different glasses of a gradually decreasing temperature coefficient. The General Electric Company is using a similar seal.

To run efficiently and with a small percentage of ballast resistance, we found it necessary to maintain the vapor inside the quartz lamp below saturation. To obtain this, one must give the lamp the proper dimensions and provide means for considerable cooling of the electrodes, either by giving the electrode containers rather a large radiating surface or by artificially cooling the same.

In the usual types of quartz lamps for efficient ultra-violet ray productions both electrodes are of mercury.

As the energy consumptions at the two poles are different, migration of the mercury takes place towards the cooler pole. This is counteracted by properly proportioning the two electrode containers. Besides, we equip the negative pole with a conic restriction. If this cone becomes too full of mercury the electrode surface is restricted and its temperature is thereby raised. Increased evaporation thus results, which causes the mercury level in the cone to be lowered; that is to say, the level in this electrode maintains itself automatically (Fig. 3).

Many trials have been made to replace the mercury by alloys which would yield more ultra-violet. It seems doubtful, however, whether this can be accomplished industrially, as difficulties are experienced with the attack on the quartz and the coating of the inside of the luminous tube. I found very strange forms of attack on the quartz when metals like copper are added to the mercury. These metals segregate themselves from the mercury in the negative electrode and penetrate deep into the wall of the reinforced quartz, producing thereby radical fissures of the walls. Inside these fissures the foreign metal deposits itself in thin sheets. In short, it seems best to avoid the contact of the arc with any metal but mercury.

Quartz, unfortunately, absorbs all wave-lengths below $.2\mu$. As these are very strongly abiotic, we thought it of interest to study how far naked spark discharges—aluminum and cadmium—would be applicable, as their spectrum is rich in short wave-lengths. Considering, however, that air absorbs in thin layers practically everything below $.1815\mu$, it is somewhat doubtful whether it would be practical to construct apparatus where we could use these shorter wave-lengths to advantage in sterilizing water unless the sparks are produced under the water, as Kowalsky proposed some time ago. However, there is always the disadvantage of demanding an elaborate high-tension arrangement for the production of the sparks, and no means have yet been found to avoid the terrific noise produced by such sparks.

We need consider, therefore, only the *mercury quartz lamp* as an industrial source of ultra-violet, and the research and technical work done with them for the purpose of industrial sterilization.

As I had the pleasure of being connected with most of the

work done at the Sorbonne University in this line, I will refer to this work and the conclusions that we arrived at.*

To start with, we had to determine whether the ultra-violet rays produced by a quartz lamp would yield enough abiotic power to sterilize water. In the majority of cases we found that an exposure of a fraction of a second (in some cases one-twentieth) close to the lamp would result in the death of the microbes. As might be expected, we found that the abiotic power diminished about as the square of the distance from the lamp. We then determined the relative resistivity of different germs to the light, and found that they do not vary as much in their resistivity against ultra-violet as in their resistivity against heat and disinfectants. For instance, spores are often twenty times as resistant as the unprotected forms of germs against chemicals, while against ultra-violet light they are only 1.5 to 5 times as resistant as ordinary unprotected water bacteria.

Fig. 4 shows a comparison of the resistivities of different types of germs; in each case cultures were made under similar conditions and the free germs put into clear water, care being taken to avoid clumps of bacteria and presence of the culture medium, for otherwise the germs would have been protected more or less against the rays.

It has sometimes been thought that the bactericidal action of the ultra-violet rays was due to a small amount of hydrogen per-

* Publications by Henri, Helbronner, and von Recklinghausen: *Comptes rendus de l'Académie des sciences*, January 3, 1910; April 11, 1910; October 17, 1910; February 28, 1910; July 24, 1911; August 14, 1911; July 22, 1912; August 5, 1912; August 19, 1912; October 28, 1912.

La Presse Medicale, January 12, 1910.

Le Génie Civil, October, 1910.

The Association of Water Engineers, July, 1911.

Congresso Internazionale delle Applicazione Elettriche, Torino, 1911.

Journal de Physiologie et de Pathologie générale, November, 1911.

Société de Chimie-Physique, June 12, 1912; June 26, 1912.

Comptes rendus de la Société de Biologie, June 15, 1912.

Journal für Gasbeleuchtung und Wasserversorgung, October 26, 1912.

Société de Médecine Publique et de Génie Sanitaire, December, 1912.

Bulletin de la Société internationale des Electriciens, March, 1913.

Electrical World, July 26, 1913.

Engineering Record, August 2, 1913.

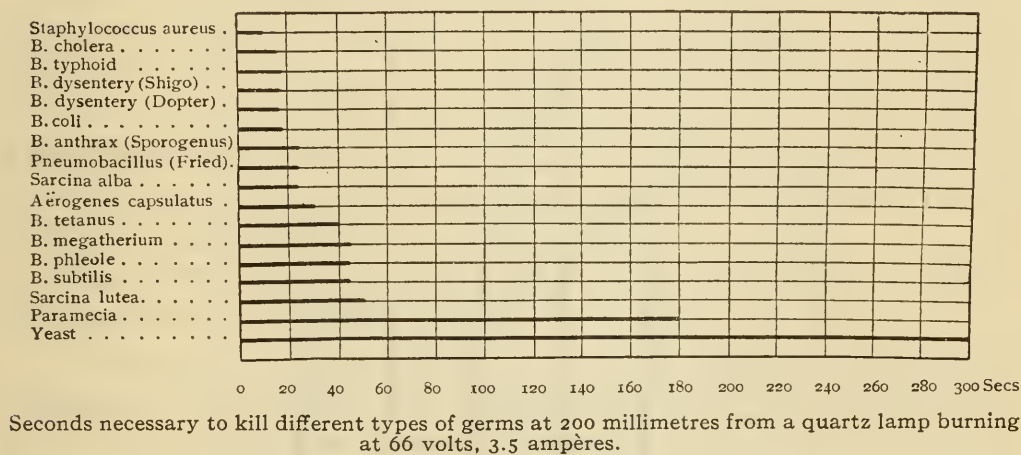
Engineering News, August 21, 1913.

Journal of the American Water Works Association, September, 1914.

oxide which indeed forms itself by the exposure of water to the ultra-violet rays. However, this formation is so minute that it is barely noticeable after ten hours of exposure of the water, and we can positively state that the bactericidal effect is not due to the action of a so-formed disinfectant, because the amount of hydrogen peroxide which can possibly form itself during the time and at a distance which is necessary to kill the microbes is only about one fifteen-thousandth of the amount which would be necessary to act as a successful disinfectant.

The abiotic action is independent of the temperature between zero and 55°. We also found it to be the same in clearly frozen

FIG. 4.



ice as in water. It is surely not probable that by the action of the rays during the short time necessary to kill the bacteria the entire bacteria should be chemically changed, coagulated or otherwise modified. It is more probable that some ferment or similar product contained in the cell is modified by the rays and thereby the system of the cell is poisoned.

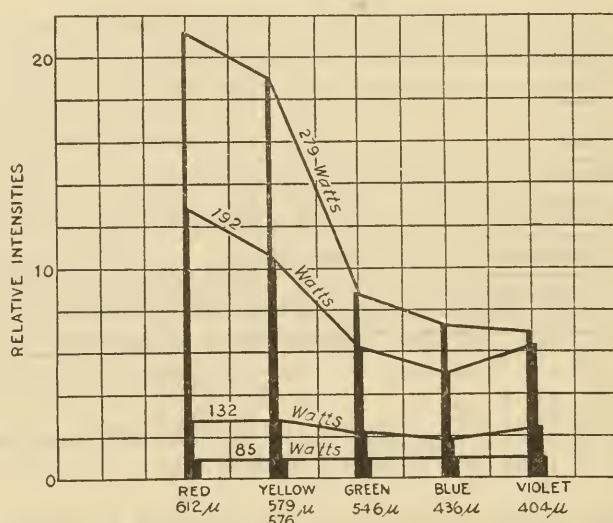
As the mercury vapor lamp can be run at different temperatures by increasing or decreasing the voltage on the electrodes, it was of interest to study the influence of the electric characteristic of the lamp on its abiotic power. As will be seen hereafter, we found that this power increases greatly with increasing lamp temperature. This is somewhat surprising, as the red part of the spectrum increases in power much more than the violet end with increasing lamp temperature. We found this from the following experiment (Fig. 5). We took an ordinary 110-volt quartz

lamp and made a spectrophotometric analysis of the five principal colors composing the visible light of these lamps. As the table shows, an increase in watts,—that is to say, of temperature,—produced a much greater increase of the red and yellow than of the blue and violet. As will be seen later on, the ultra-violet end of the spectrum increases about like the red end; that is to say, it increases in power much more than the blue and violet visible rays.

These experiments led us to go somewhat more fully into the question of measuring the ultra-violet candle-power of our lamps, and we come to the following considerations:

The candle-power standard for ordinary light is not a physical

FIG. 5.



standard, but a physiological one, being the effect on the eye of the sum of the visible wave-lengths emitted by a defined source of light; that is to say, a standard candle.

The eye not being sensible to ultra-violet, we consider only the total visible energy sent out by this standard lamp. If we want to define a standard of *ultra-violet* light, we must either define in energy units the power of each individual wave-length or we must imitate our method of defining the standard of ordinary light and define our standard of ultra-violet as the unit total effect produced by the ultra-violet rays. However, as effects on chemical reactions and perhaps biologic reactions may be influenced in a different and irregular way, by different wave-lengths, it is probable that the sum of such effects may be identical if one kind of reaction is chosen, and may not be identical if

another kind of reaction is chosen. The only true way of defining the power of the rays is by the analysis of the spectrum and the determination of the energy sent out by each wave-length. This is evidently right from the physical point of view, but inconvenient in practice. We therefore thought better to choose as a unit some value of the particular reaction which concerns the work in hand. If we want to follow chemical reactions under the ultra-violet light, we choose arbitrarily as a unit one in which the desired reaction takes place in a defined way after a unit period of exposure to all the rays of the lamp. We may therefore say that for every type of reaction under the light we have to define a new unit of activity.

In a practical way it is impossible to work only with ultra-violet radiations, for we have to consider all radiations which the lamp sends out. There are, unfortunately, no filters known which will let *only* and *all* the ultra-violet rays pass, although we have some filters which will take out all the visible rays and allow a fraction of the ultra-violet rays to pass, such as blue salt crystals and, particularly, colloidal silver solutions.

The following methods for examining the power of ultra-violet radiations could be considered:

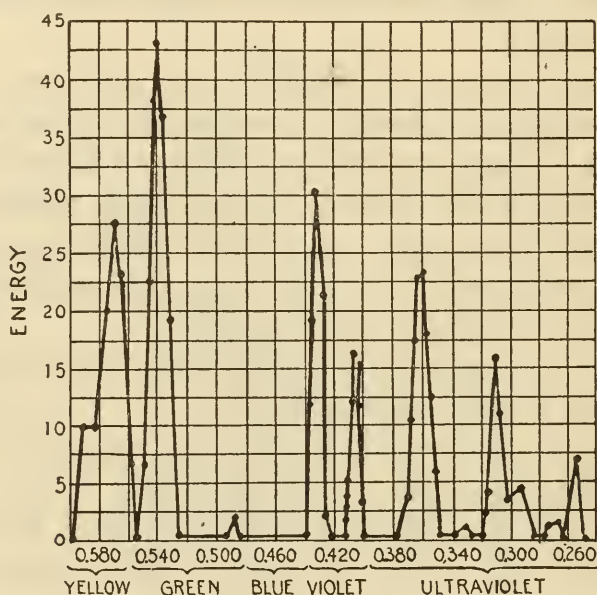
1. Analysis of energy of individual wave-lengths by means of bolometer or thermocouple, as shown in Fig. 6, for the mercury lamp (Ladenburg): Fabry used screens to divide different groups of wave-lengths sent out by a mercury lamp running at a low temperature, and found by this method the following distribution of energy: 93.7 per cent. in the infra-red, 3.6 per cent. in the visible light, 2.7 per cent. in the ultra-violet light.

2. Ultra-violet light falling on a condenser will ionize the air, and this will be followed by a discharge of the condenser. So far as I know, this has not as yet been used for analyzing ultra-violet spectra.

3. Photochemical reactions were chosen. Usually they are strongly influenced by ultra-violet light. For instance: the blackening of photographic paper goes on four times more quickly under a naked quartz lamp than under the same lamp with glass interposed. We can build a sensitometer of paper, using this blackening as indication of the power of the light. If we expose the different wave-lengths separately, that is to say, in a spectro-photographic apparatus, to the photographic plate we must con-

sider that we can thereby compare only the strength of individual lines of equal wave-lengths coming from different sources by comparing the time of exposure necessary to obtain equally strong pictures of such lines. With chemical reaction, like the exposure of f. i. photographic paper (nitrate of silver) to all the rays of a lamp, it is fairly easy to define a standard unit of effect, as the same chemicals will be equally sensible to the same amount of light. If, however, we choose a unit of bacterial reaction, we find that our reaction will depend very much on the *quality* of the

FIG. 6.



bacteria we submit to the light. Although produced under identical conditions, the same kind of microbes vary very much in their resistivity against light. This means that it will be impossible to get sufficiently constant abiotic results upon which to base a unit reaction. We must therefore create a laboratory standard of ultra-violet light and determine with this the sensitivity of our biologic agent, our culture of microbes. After having defined this resistivity we can use the same culture to define the power of an unknown lamp which we want to determine.

The abiotic reaction which we choose as most convenient to handle was the exposure necessary to kill paramecias, these being similar to water-bacteria and easy to cultivate and to observe directly under the microscope, as they have a very violent motion when living and, naturally, no motion when dead. We expose a

drop of such culture at a defined distance from the lamp, and count the seconds necessary to render them motionless. We obtain thereby comparative figures of the abiotic power of our standard lamp and of the unknown lamp.

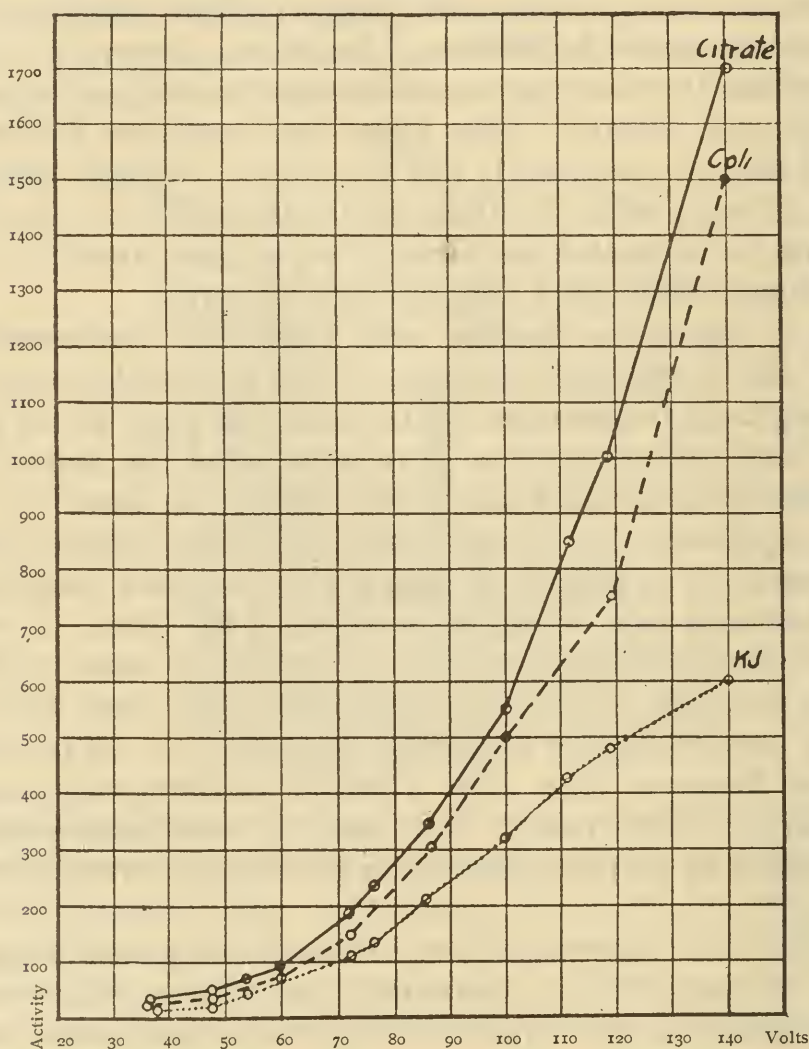
As the photographic paper method is much simpler to handle, we compared the figures obtained therewith with the abiotic reaction so as to see whether this simple method would not give a sufficiently precise indication of the abiotic power of a lamp. Fig. 7 shows the observations made simultaneously of exposing bacterium coli, citrate of silver paper, and potassium iodide to a lamp which was successively run at different voltages, using, of course, arbitrary units of activity for the three different reactions. This table shows us that the citrate of silver paper reaction comes close enough to the direct measurements on germs.

Fig. 7 shows us another very important phenomenon,—namely, the considerable increase of the ultra-violet rays with increasing lamp temperature; that is to say, it gives us the proof that a lamp will deliver the more ultra-violet the hotter it is. We naturally have to use care in not running the lamp up to too high a temperature, as we know that quartz thus becomes gradually opaque. It is difficult to measure the absolute temperature of the luminous tube during the working of the lamp. It seems, however, that this luminous tube will not absorb more than perhaps 25 per cent. of the ultra-violet light after 3000 hours, if run at a temperature not exceeding about 700° C. If run above 800° , the luminous tube, after a period, becomes very opaque, particularly to ultra-violet. It is easy to avoid such excessive temperatures by properly controlling the flow of current through the lamp.

Having thus determined how to handle the quartz lamp and having, as said before, determined the relative resistivity of different germs to the ultra-violet rays, there remains only to be determined the principle on which to design proper apparatus for leading the water at the right speed through a zone which is illuminated by an efficient lamp. The following point had to be considered, in designing the apparatus: Water is practically as transparent as air to ultra-violet rays, provided it is clear; that is to say, in many cases it will first have to be filtered to free it from suspended matter, and, if possible, also from colloidal matter, which would otherwise retard the passage of the rays.

Careful observation of well-filtered water will, however, nearly always reveal the presence of a small amount of suspended matter of a large enough size to allow microbes to be protected against the rays. To sterilize such water with safety, we found it useful to agitate it while passing through the illuminated zone,

FIG. 7.

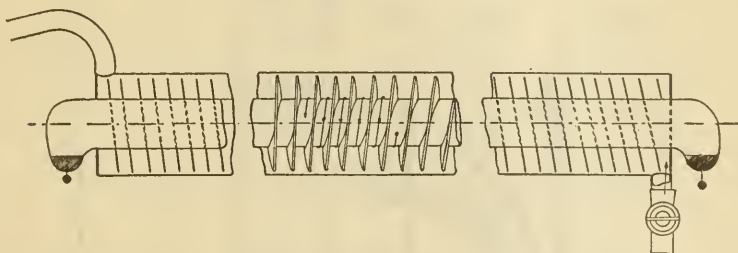


Comparative measure of ultra-violet activity of 220-volt quartz lamp burning at different voltages by three methods: (a) Decomposition of citrate of silver; (b) decomposition of potassium iodide; (c) annihilation of bacterium coli.

and to expose it several times to the light of the same lamp or to several lamps in succession; thus small suspended matter is exposed on all sides to the action of the light. The automatic stirring up is best accomplished by a proper arrangement of baffle plates in the apparatus, which are so placed as to create a minimum of shadows.

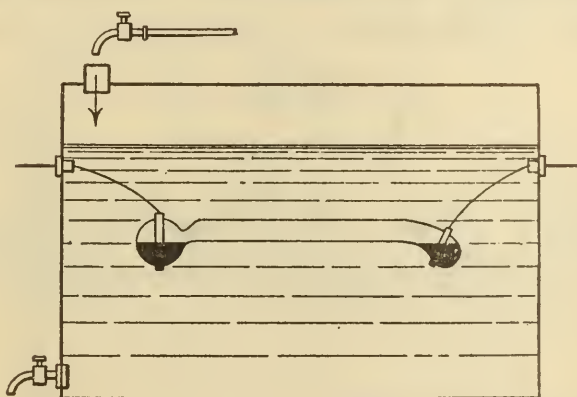
The first mercury lamp water sterilizer was invented by De Mare in 1906, and is shown in Fig. 8. Some years later Courmont and Nogier placed a mercury lamp in a barrel of water, submerging the lamp completely into the water (Fig. 9). This seemed at first a most efficient way, because all the rays from the lamp entered the water. After examining the ultra-violet

FIG. 8.



efficiency of such a lamp burning directly in the water, we found it, however, to be very much impaired by the cooling effect of the water. Fig. 10 shows the activities measured of the same lamp in the water in the open air and enclosed in a casing (which decreased the radiation from the lamp and thereby increased its temperature). Apart from this, deposits form easily on lamps

FIG. 9.

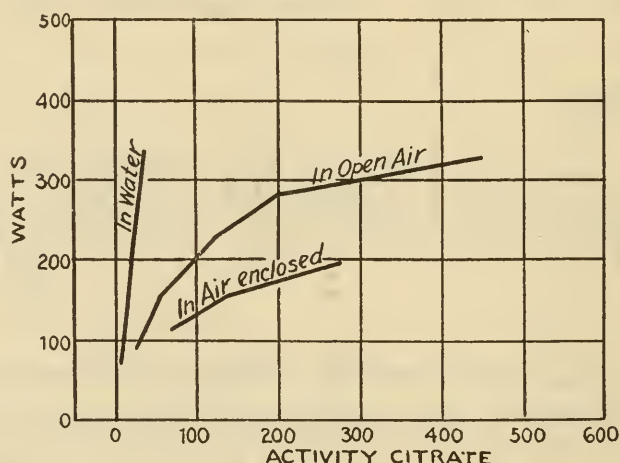


which are in direct contact with the water, rendering the luminous tube thereby opaque. Our first experiments with running water were made in an apparatus shown in Fig. 11, and from this we developed the apparatus shown in Fig. 12, which contained the stirring baffles described above. Our first experiments on a large scale were made with a canal (Fig. 13), equipped with several lamps placed on floats close to the surface of the water.

A small sterilizer is shown in Fig. 14. Its characteristic part

is the lamp. Its electrode containers are cooled by the water of the sterilizer itself. The luminous tube, however, is above the water. Such a burner represents the simplest type of mercury vapor quartz lamp. In all these types only the light sent down-

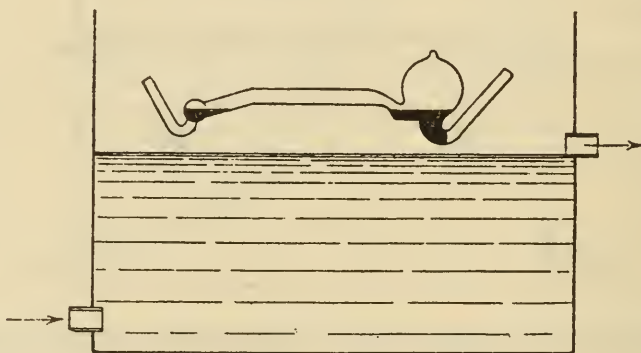
FIG. 10.



wards from the lamp enters the water, as it is almost impossible to reflect ultra-violet rays.

For the purpose of using all the rays of the lamp and eliminating the cooling effect of the water on the luminous tube caused by the submersion of the lamp, as shown in Fig. 9, the Quartz

FIG. 11.



Lampen Gesellschaft sealed a quartz jacket over the lamp, as Fig. 15 shows. However, these lamps were difficult to manufacture. We therefore constructed the apparatus shown in Fig. 15, where the sterilizing tank is equipped with a lamp box to which quartz windows are fitted. The lamp can easily be inserted into this box, and its light shines through the windows into the water, the

FIG. 12.

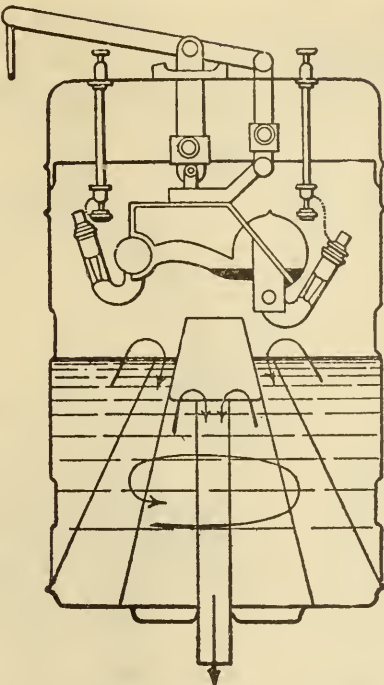
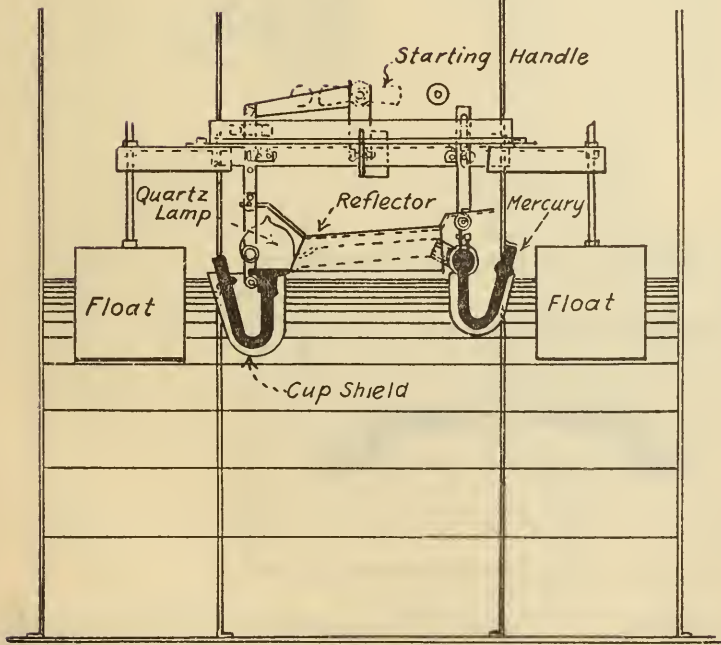


FIG. 13.



lamp itself being protected from the cooling effect of the water by the box.

Another way of using all the light emitted by a lamp without

allowing the lamp to be touched by the water and cooled thereby is shown schematically in Fig. 17, where the water flows in a concentric waterfall alongside the lamp, or, as in Fig. 18, where it is forced by centrifugal force in a helical path around the lamp.

FIG. 14.

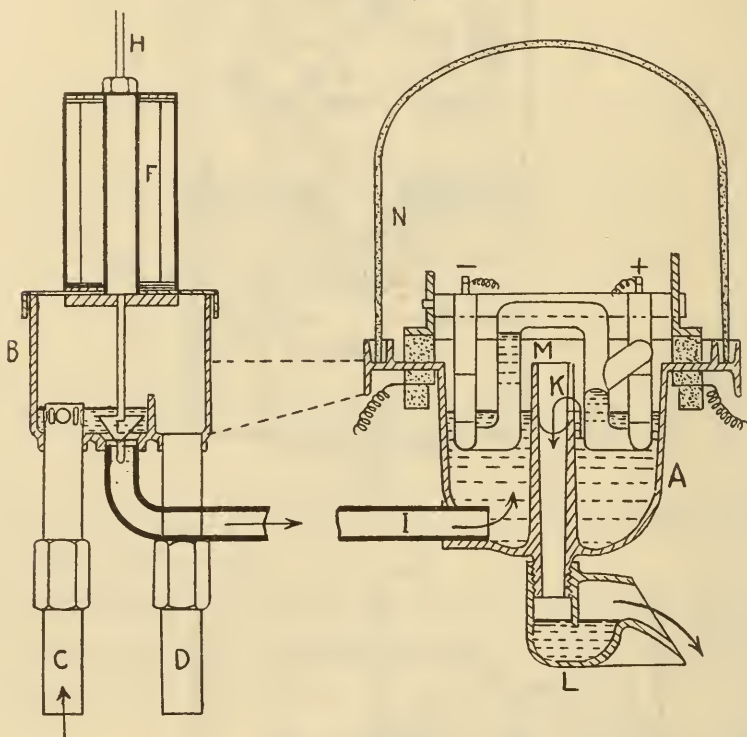
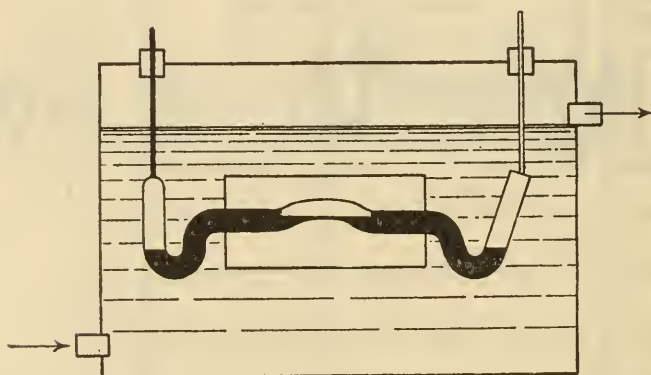


FIG. 15.



In the end, however, I found it preferable to change the shape of the lamp,—namely, by bending the luminous tube in a closed U shape, with the cumbersome electrodes on one side only. From the shape so obtained I have called these “Pistol” lamps. They are shown in Fig. 19. The luminous part of these lamps

FIG. 16.

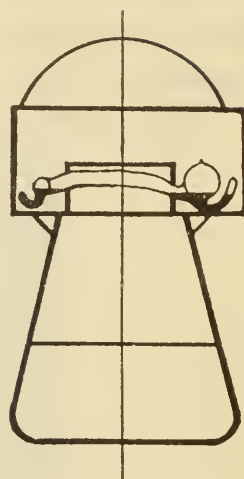
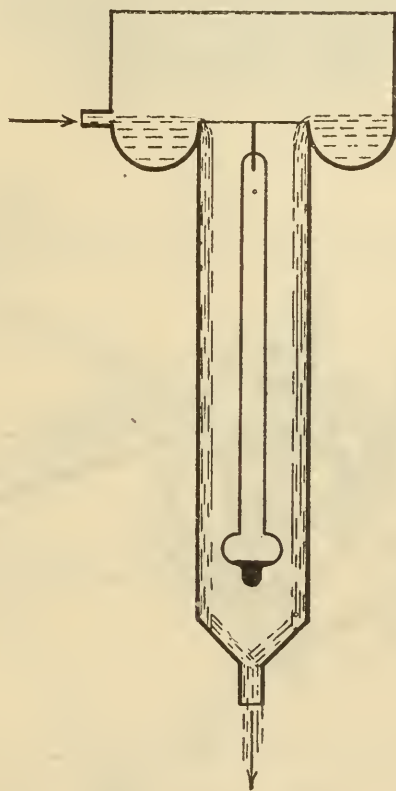
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FIG. 17.



is inserted into a quartz tube which is fitted hermetically to the walls of the sterilizing tank. Figs. 20 and 21 show such apparatus. This arrangement furnishes a simple way of placing several lamps into the same tank, allowing thereby large amounts

of water to be sterilized in a single apparatus. Figs. 22 and 23 show the schematic arrangements of the sterilizing canals made possible by these pistol lamps.

Fig. 24 shows the installation of such a sterilizer for the con-

FIG. 18.

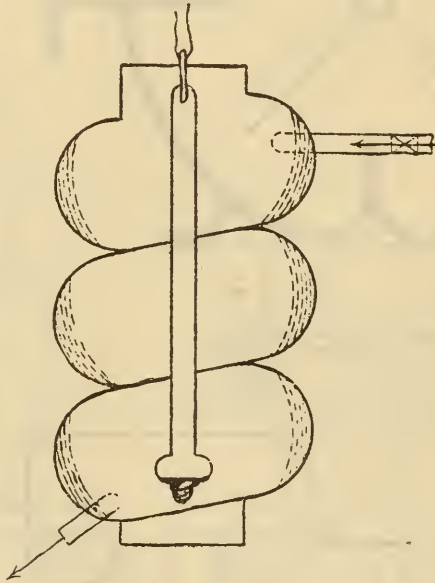
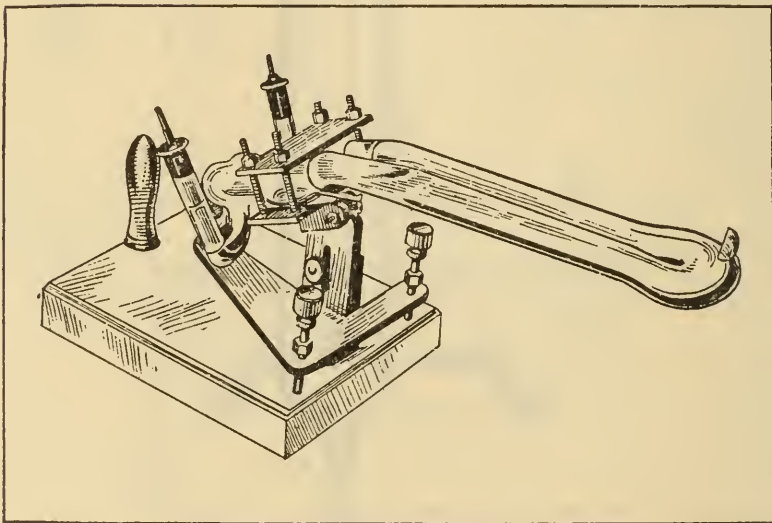


FIG. 19.



tinuous purification of the water for a large swimming tank, which is subject to continual contamination by the bathers. Fig. 25 shows a large city installation using a ten-lamp canal in the city of Luneville, France.

It is interesting to note that the hygienic results obtained with

FIG. 20.

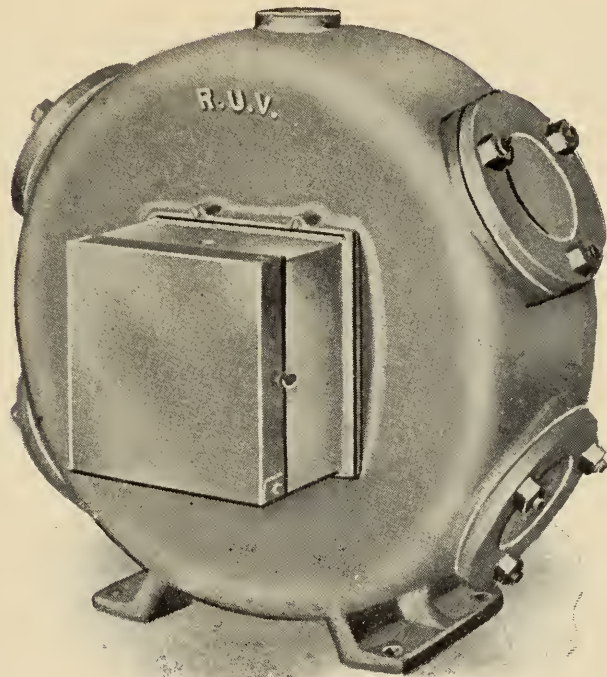
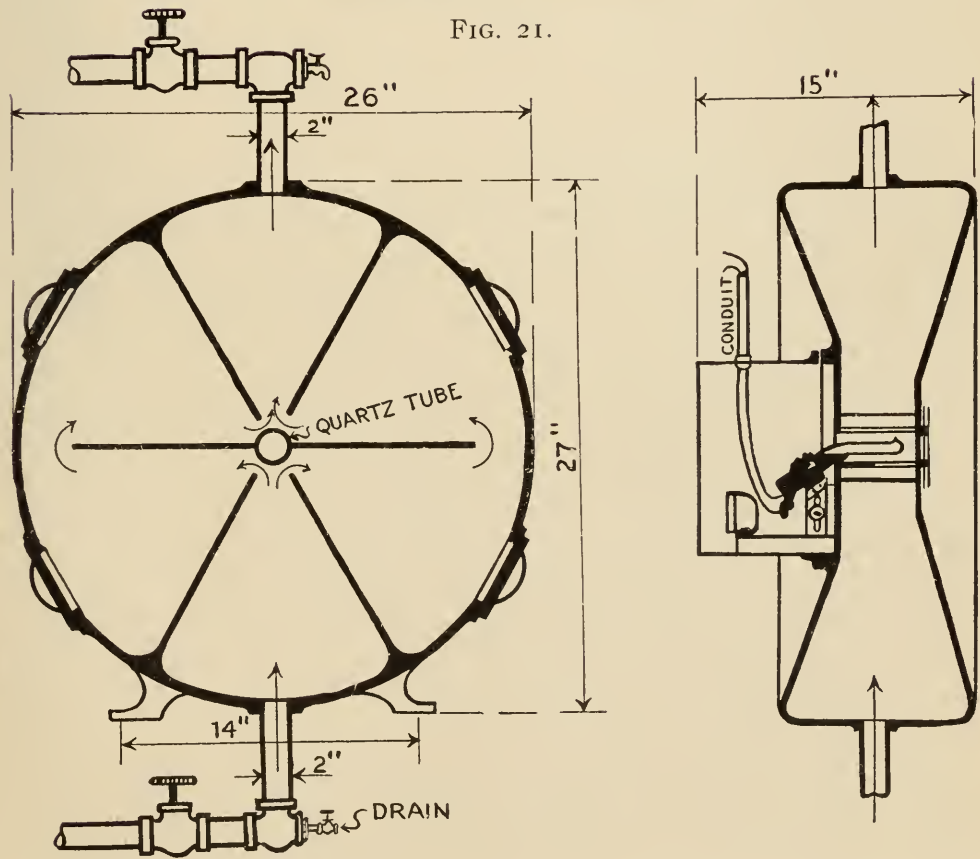
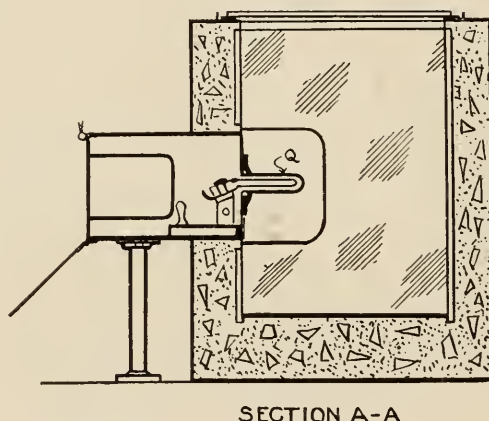


FIG. 21.



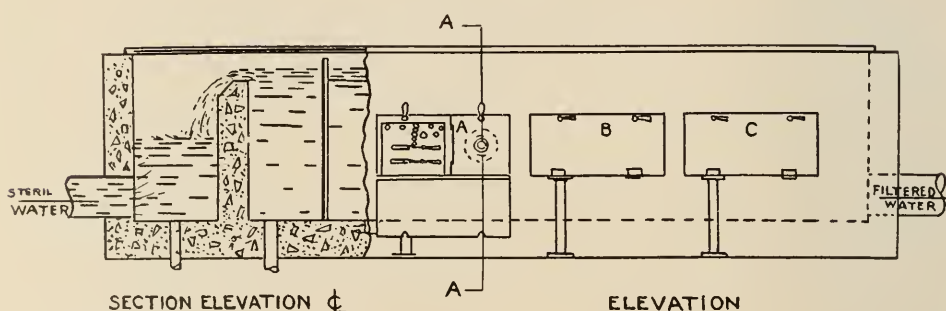
this Luneville plant are extremely satisfactory and prove better than any tests the importance of this system, as typhoid fever has been practically eliminated from this town since the introduction of this sterilizing system. Several large plants of the same type of apparatus are under construction.

FIG. 22.



If the water is used for drinking purposes, one can easily run the sterilizer so as to remove surely all pathogenic bacteria. A very short exposure of a minute or two in the large city water sterilizers is sufficient for this, provided filtration has previously removed the matter suspended in the water. The energy con-

FIG. 23.



sumption in such cases is extremely small and varies between 50 and 130 kilowatt-hours per million gallons of water, allowing for very large safety coefficients.

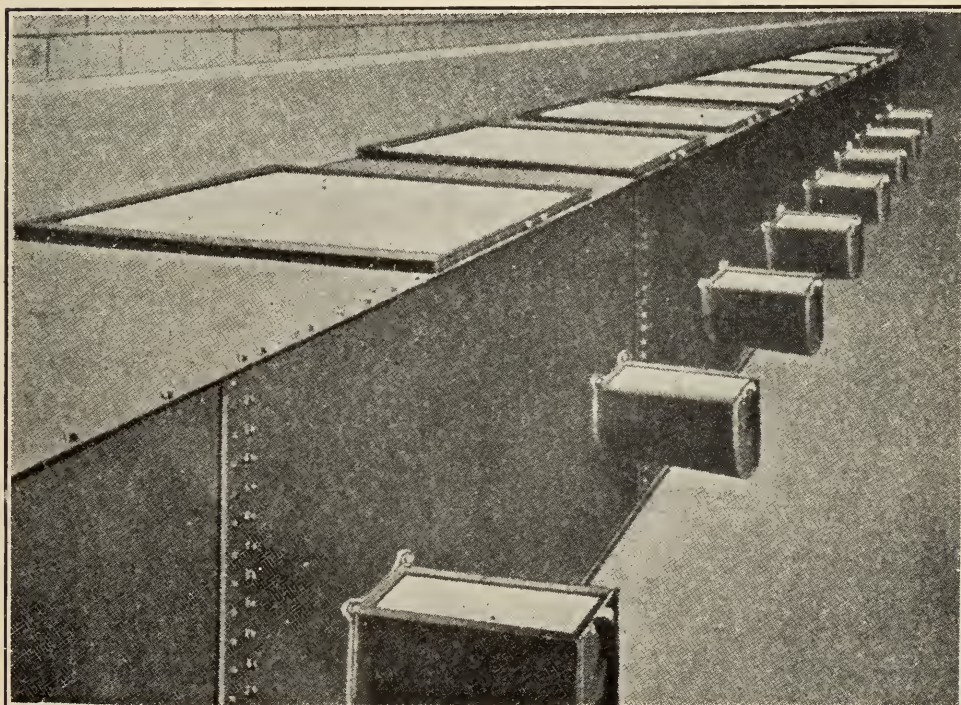
If the water is used, for instance, for surgical purposes where absolute sterility is of importance, the smaller apparatus is used, and the exposure is so arranged that surely no microbes will

FIG. 24.



Swimming pool of the new West Side Y. M. C. A., showing the R. U. V. installation.

FIG. 25.



Sterilization plant in the city water works, Luneville (France).

escape the abiotic action of the rays. In a clear water a few seconds' exposure in such apparatus will completely annihilate germ contents of thousands of germs per cubic centimetre.

The transparency of clear water to ultra-violet rays renders the sterilization of water, even on a larger scale, very simple and, as experience has proven, perfectly practical.

If we now come to the sterilization of opaque bodies, we find that the problem is very much more difficult. The penetrating power of ultra-violet through opaque bodies is in every case much less than the penetrating power of visible light. If we try, therefore, to sterilize opaque bodies, we must submit them in such thin layers that the light will penetrate to the far layer of such a film, so that even this is sterilized and cannot reinfect the part of the film which is nearer the lamp. Many experiments have been made by ourselves and others in attempts to sterilize milk. Some of the experiments have been only partly successful because the milk was exposed in too thick a layer. It is, however, perfectly feasible to obtain successful sterilization if one uses the precaution to spread out the milk thin enough, and particularly if one takes very fresh milk,—that is to say, milk containing young microbes.

The mechanical difficulties of obtaining a thin film have so far prevented the industrial application of the ultra-violet rays for the sterilization of milk. I believe, however, that it will soon be attained.

Ultra-violet rays not only kill bacteria but they also destroy toxines, as many laboratory experiments have proven. This fact seems to give an explanation of the healing effect of the light bath, the effect of which was always somewhat mysterious. It seems to me quite possible that the blood is exposed right near the skin during its circulation from the artery to the vein system to the ultra-violet light and gets more or less sterilized thereby and freed of its toxine contents. I understand that lately experiments with tuberculosis patients who were exposed to quartz lamps have given excellent results, widening thus the field of the application of the ultra-violet rays.

Ultra-violet rays have been used for many reactions, such as bleaching and the production of chemical compounds. None, however, have attained the industrial application that the sterilization of water has accomplished.

NOTES ON CATENARY CONSTRUCTION OF NEW YORK, WESTCHESTER AND BOSTON RAILWAY.*

BY

SIDNEY WITHINGTON,

Assistant Engineer, New York, New Haven and Hartford Railroad.

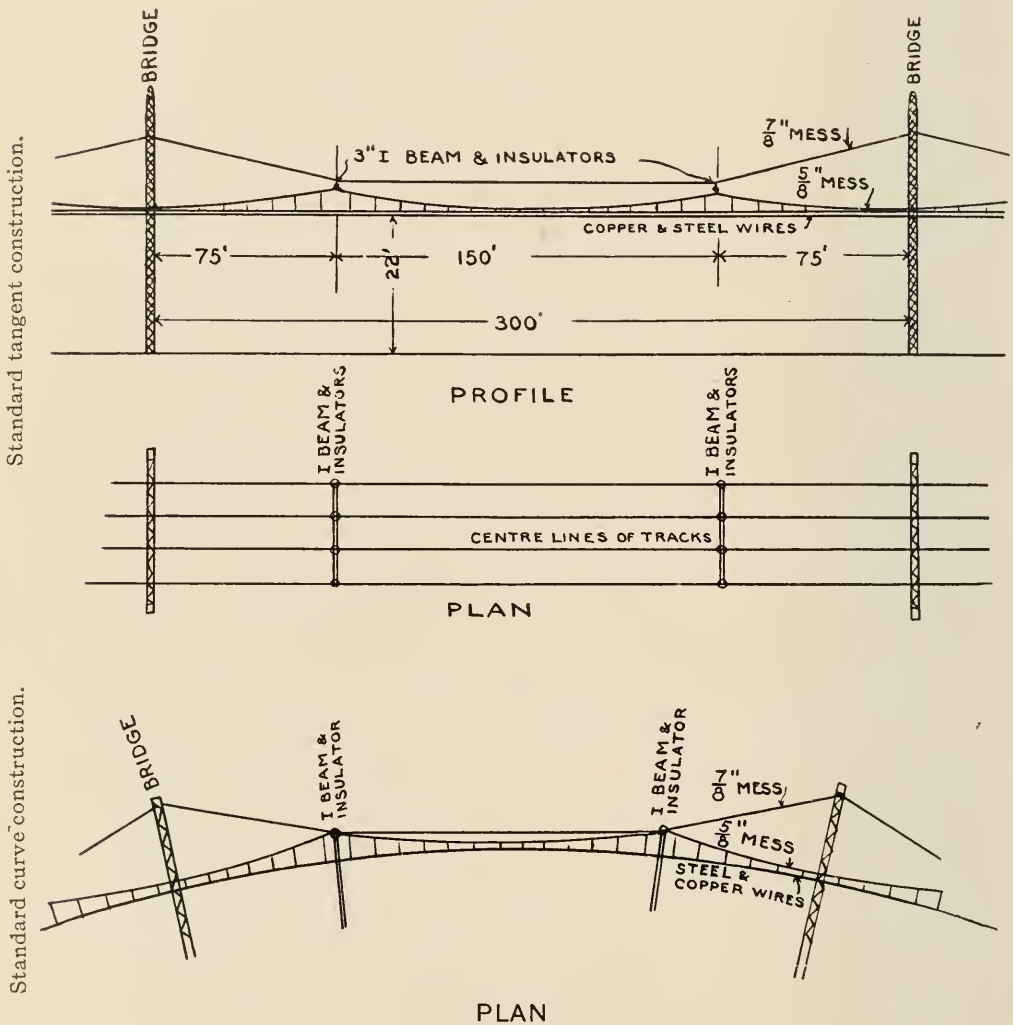
THE problem of distribution of high-voltage electric power (either alternating or direct current) to trains moving at very high speeds resolves itself into locating an aërial wire (or two wires for three-phase power) out of reach of persons walking on or crossing the track, and in such a position that it may be easily reached at all points by the collecting apparatus of the locomotive. Vertical variations in location of the wire with respect to the track, if they are necessary (as at highway bridges, etc.), should be gradual, so that the collecting devices will suffer as few sudden changes in position as possible, and so that the pressure of the shoe against the wire will not have to be increased to prevent the shoe being thrown away from the wire, causing arcing. There should be as few "hard" spots in the wire as possible; that is, the pressure of the collecting devices should displace the wire at the point of contact everywhere along the line in equal amount. Spots where the support of the wire is too rigid will cause shocks, and the contact wire will become hard and eventually break.

The contact system of the New York, Westchester and Boston Railway, installed about 1912, consists of a 4/0 grooved steel "contact" wire of standard section, supported approximately every ten feet by malleable iron clips from a 4/0 grooved copper wire of similar shape, $1\frac{3}{4}$ inches above it, and in the same vertical plane. This copper, or "trolley," wire is in turn supported from a $\frac{5}{8}$ -inch steel strand by hangers of variable length, in such a way that it lies in a straight line parallel to the track. The hangers are $\frac{1}{2}$ -inch steel rods screwed at each end into malleable iron clamps. On tangents the hangers are located midway between the clips supporting the contact wire, and on curves the hangers and these clips are combined, the flexibility being obtained by the inclination of the hangers from a vertical plane normal to the track. The

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hangers are clamped to the $\frac{5}{8}$ -inch strand and to the copper wire on tangents, and the clips supporting the steel contact wire from the copper trolley are tightly fastened to the former and hang loosely from the latter. On curves the hangers are clamped tightly to the messenger and to the steel contact wire, but loosely around the copper.

FIG. 1.

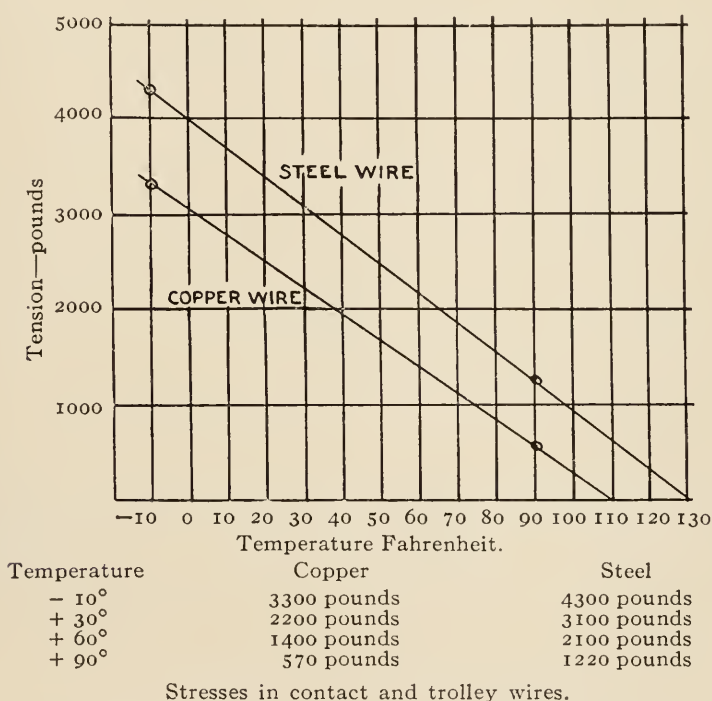


The $\frac{5}{8}$ -inch messenger or "track messenger" is supported by a suspension insulator from an *I*-beam of standard section, 3 inches x $5\frac{1}{2}$ pounds per foot, located horizontally, normal to the centre line of the tracks, extending over them all and tying the track wires together mechanically. The *I*-beams are located at the quarter points of each span, and are clamped to the $\frac{7}{8}$ -inch steel strands (one strand over each track). These $\frac{7}{8}$ -inch or

“main messengers” are grounded, and, besides supporting the catenary system, serve as an addition to the “ground return” for the traction power, and as a protection against lightning. They are supported by structural steel bridges on malleable iron saddles, and are tightly clamped to each bridge by “U” bolts.

The contact wire lies closely parallel to the centre line of the track, both on tangent and curve; that is, there are no sudden bends or corners in the wire, which follows curves smoothly. The normal clearance is 22 feet above the top of the rail, and the steepest grade with respect to the track is 1 per cent. (see Fig. 1).

FIG. 2.



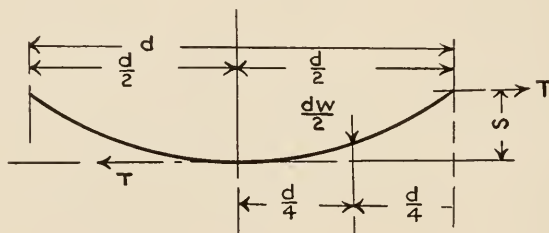
For curves sharper than 4° , pull-off poles were installed midway between the catenary bridges, pulling the $\frac{7}{8}$ -inch messengers over far enough to relieve the bridges of any stress in excess of that normally produced by a 4° curve, the trolley wires and $\frac{5}{8}$ -inch messenger being also pulled off so that the curve consisted of a series of 4° arcs. (In two special cases two pull-off poles were provided in each span, located at the end of each of the I-beam frames.)

In erecting the system, the $\frac{7}{8}$ -inch messengers were first pulled out over all tracks and laid in the malleable iron saddles which

had been clamped to the catenary bridges. Then the strands were pulled up to the required tension, as indicated by the sag. The proper sag was obtained for each span by means of a light bamboo pole with a target at the end and with a sliding hook which could be clamped at any desired position on the pole. This pole was hooked on the messenger and the tension was adjusted so the adjacent saddles and target were in a straight line.

When the $\frac{7}{8}$ -inch strands had all been sagged, the next step was to install the *I*-beam frames and insulators. This was carried out from a large tower car, which was located on one of the centre tracks, and which was provided with collapsible wings for working over the two neighboring tracks, and from a small hand tower car on the fourth track. The insulators and fittings were installed with the *I*-beam frames.

FIG. 3.



The next step was to string the $\frac{5}{8}$ -inch messenger, which was done by anchoring the end and running out the reel on a flat car, the strand being inserted but not clamped in each insulator as it was passed. Every few hundred feet the strand was pulled to the proper sag and clamped.

The trolley and contact wires were strung simultaneously in the same manner as the $\frac{5}{8}$ -inch messenger, the wires being temporarily suspended at intervals from the $\frac{5}{8}$ -inch messenger by pieces of wire of about the same length as the hangers.

The hangers were made up in bundles, or sets, of the proper number and lengths for each span—as laid out from track data in the draughting room—and were installed from the top of a train of tower cars, one complete span (150 feet) at a time. The clips between the copper and steel wires were put on at the same time.

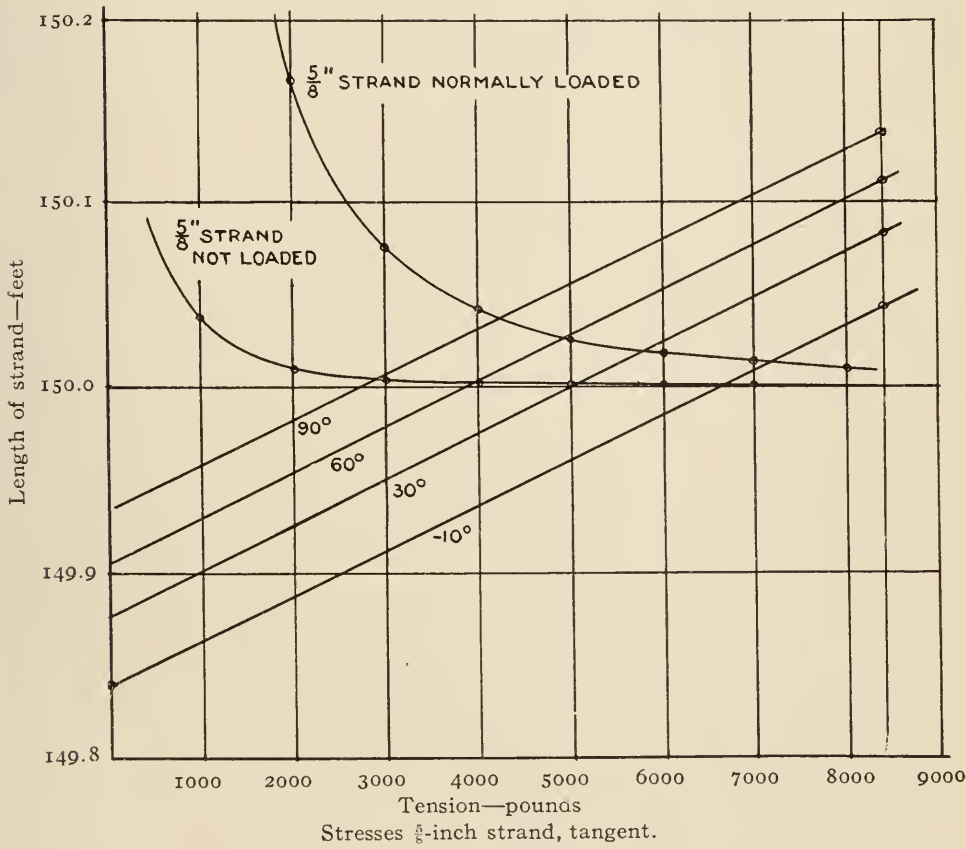
In laying out the hangers, it was arranged that each set should

be located symmetrically to an *I*-beam support, so that changes in length of span or from tangent to curve, or from one degree curve to another, should occur at the “low ” point of the catenary. In this way, nothing but complete bundles of standard lengths of hangers were handled by the crew occupying track in the installation of the catenary system.

The data furnished to the field forces were :

1. Location of the saddle castings on the catenary bridges with respect to the track centres (since many of the saddles had to be

FIG. 4.



installed before the tracks had been laid, the track spacing was also given at each bent location).

2. Proper sag of the main messenger strand for various temperatures without the load of the catenary system upon it.

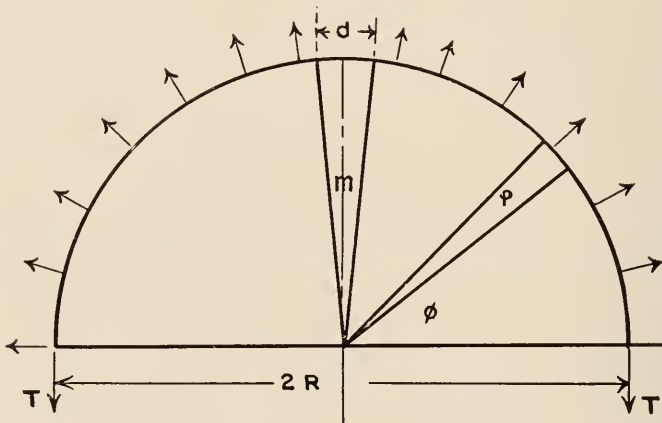
3. Locations of the *I*-beam frames with respect to the steel bridges and the track spacing at each *I*-beam location ; also, where special hangers are used between main messenger and *I*-beam, the lengths of such hangers.

4. Proper sag of $\frac{5}{8}$ -inch strand, not loaded, for the various spans at different temperatures.

5. Appropriate set of hangers for each span, and tension in the trolley wires.

The normal span is 300 feet on tangent tracks and on 1° and 2° curves, 260 feet on 3° curves, and 200 feet on 4° curves, the secondary catenary span being half these figures in each case. The messenger strands are "extra high strength steel," 19-wire, extra heavily galvanized, with an ultimate strength of about 175,000 pounds per square inch. The hard drawn copper grooved wire has an ultimate strength of about 50,000 pounds per square inch, and the steel grooved contact wire about 100,000 pounds per square inch.

FIG. 5.



It was the intention, in laying out the system, to arrange the tensions in the various members so that at 60° F. the stresses in a member should be everywhere the same. If this condition exists at 60° F., equilibrium will not exist between tangents and curves, or between long spans and short spans, at other temperatures, but the difference is not very great, and the catenary bridges are heavy enough to take care of these unbalanced forces.

The conditions of sag, stress, etc., were figured and tabulated for use in the field for tangent and 1° , 2° , 3° , and 4° curves at temperatures of 10° F., 30° F., 60° F., and 90° F. This paper outlines the method of calculation.

The wind load assumed was thirty pounds per square foot of exposed surface, and, in the case of the wires, two-thirds of the projected area of bare wire was assumed as the effective surface.

In assuming a wind and ice load, eight pounds per square foot was taken as the maximum wind load on wires, it being considered that very high winds would blow off the ice or sleet, leaving the wires bare. The ice or sleet load assumed was a coating $\frac{1}{2}$ inch thick on all surfaces (weight of one cubic inch of ice = 0.033 pound).

The modulus of elasticity of steel wire was taken as 29,000,000 pounds per square inch; of steel strand as 26,000,000, and of copper wire as 17,500,000. The coefficient of expansion per degree Fahrenheit was taken as 0.0000064 for steel wire and steel strand and as 0.0000094 for copper wire.

General data of weights, areas, stresses, and loads are given in Table I.

TABLE I.

Material	Ultimate strength, lbs.	Allowed stress, lbs.	Cross-section, sq. in.	Weight in pounds per foot		Wind load in pounds per foot	
				Bare wire	With ice	Bare wire	With ice
4/o grooved steel.....	16,600	4,300	0.166	0.558	1.158	0.800	0.660
4/o grooved copper....	8,300	3,300	0.166	0.641	1.241	0.800	0.660
$\frac{5}{8}$ -inch strand.....	45,000	9,000	0.237	0.810	1.506	1.040	0.745
$\frac{7}{8}$ -inch strand.....	90,000	18,000	0.498	1.700	2.552	1.460	0.835
Hangers.....	....	....	....	0.177	0.254	0.100	0.100

The following symbols are used in this discussion:

- d =Span between supports, feet.
- w =Load on wire, pounds per foot.
- s =Sag, feet.
- T =Tension (total, in wire), pounds.
- E =Modulus of elasticity.
- C =Cross section, square inches.
- R =Radius of curve of track, feet.
- A =Mid-ordinate, feet.
- F =Horizontal pull of wires normal to centre line of track, pounds.
- l =Actual length of material in given span, feet.
- a =Coefficient of expansion, ° F.

TENSION IN TROLLEY AND CONTACT WIRES, ON TANGENTS, AT VARIOUS TEMPERATURES.

The trolley and contact wires are rigidly fastened at either end, and so have a constant length at all temperatures. The maximum allowed stress (4300 pounds for the steel wire and 3300 pounds for the copper wire) was assumed as existing at -10° F.; since

the length of the wires is fixed, the stress decreases with rise of temperature.

Assume that a wire is held in such a manner that it is free to elongate or shorten at constant tension, and that the temperature is lowered so the wire shortens a inches; if now the wire is pulled so it elongates a inches and returns to its original length at this lower temperature, this elongation is proportional to the force required to produce it, and the final tension is the same as if the wire were held at constant length during the temperature change.

Change in length due to temperature change Δt°

$$l = l_0 + l_0(\alpha \cdot \Delta t) \dots \dots \dots (1)$$

Elastic change in length due to change in tension ΔT is

$$l = l_0 + \frac{\Delta T \cdot l_0}{C \cdot E} \dots \dots \dots (2)$$

Subtracting (2) from (1)

$$0 = l_0 \cdot \alpha \cdot \Delta t - \frac{\Delta T \cdot l_0}{C \cdot E}$$

that is,

$$\frac{\Delta T \cdot l_0}{C \cdot E} = l_0 \cdot \alpha \cdot \Delta t$$

or

$$\Delta T = C \cdot E \cdot \alpha \cdot \Delta t \dots \dots \dots (3)$$

At 90° F. $\Delta t = 100^\circ$ F., and for steel wire $T_{-10} = 4300$ pounds, and for copper wire $T_{-10} = 3300$ pounds. So that:

For steel wire

$$\begin{aligned} \Delta T &= 0.166 \times 29,000,000 \times .0000064 \times 100 \\ &= 3080 \text{ lbs.} \\ T_{90} &= T_{-10} - \Delta T = 4300 - 3080 = 1220 \text{ lbs.} \end{aligned}$$

and for copper wire

$$\begin{aligned} \Delta T &= 0.166 \times 17,500,000 \times .0000094 \times 100 \\ &= 2730 \text{ lbs.} \\ T_{90} &= T_{-10} - \Delta T = 3300 - 2730 = 570 \text{ lbs.} \end{aligned}$$

Since the tension variation is proportional to the temperature change, the Temperature *vs.* Stress curve is a straight line and may now be plotted (Fig. 2).

STRESSES IN FIVE-EIGHTH-INCH STRAND ON TANGENT, VARIOUS TEMPERATURES.

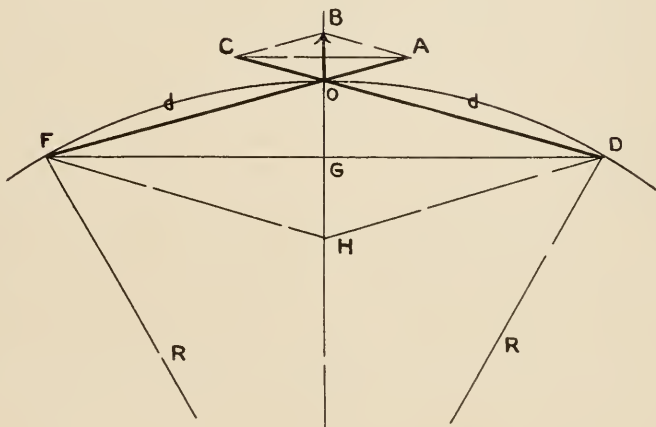
The curve assumed by the 5/8-inch messenger with the trolley wires hanging from it lies between a catenary and a parabola. The two curves lie very close together where the ratio of sag to span is small, and, as the parabola is much the simpler, it is used in these calculations.

Assume parabola, Fig. 3, loaded w pounds per horizontal foot. Take moments about point of support. T = horizontal component of tension, s = sag in feet, d = span feet.

$$w \frac{d}{2} \frac{d}{4} = TS$$
$$s = \frac{wd^2}{8T} \dots\dots\dots (4)$$

The total tension is, of course, greater than the horizontal component (the vertical component being the weight of the sys-

FIG. 6.



tem), but the total weight is so small compared to the tension that the error is negligible.

The loadings (Table I) under maximum wind load with bare wires and with iced wires are :

Bare wires.....	2.185 pounds per foot vertical.
	2.740 pounds per foot horizontal.
	<hr/>
	3.500 pounds per foot resultant.
With ice.....	4.159 pounds per foot vertical.
	2.165 pounds per foot horizontal.
	<hr/>
	4.690 pounds per foot resultant.

Thus the maximum stress occurs when wires are coated with sleet, and is 4.69 pounds per foot. The normal span is 150 feet.

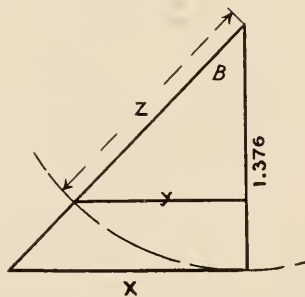
From equation (4)

$$s = \frac{4.69 \times 150^2}{8 \times 8400} = 1.57 \text{ ft. sag with wind and ice.}$$

The stress, 8400 pounds, is assumed lower than the allowed stress, since, with the stress equal throughout the system at 60°, the maximum stress is greater on curves than tangent.

The following expression for the length of a parabola is approximate only, but it is within the limits of accuracy of the field work:

FIG. 7.



$$l = d + \frac{8}{3} \cdot \frac{s^2}{d} \dots\dots\dots(5)$$

If the value:

$$s = \frac{wd^2}{8T}$$

be substituted in expression (5), we get

$$\begin{aligned} l &= d + \frac{8}{3} \cdot \frac{\frac{w^2d^4}{64T^2}}{d} \\ &= d + \frac{8}{3} \cdot \frac{w^2d^4}{64T^2} \cdot \frac{1}{d} \\ &= d + \frac{w^2d^3}{24T^2} \dots\dots\dots(6) \end{aligned}$$

Working from the above expressions, assuming that the maximum weight is 4.69 pounds per foot (resultant), the length of material in the span is, from equation (6),

$$\begin{aligned} l &= 150 + \frac{4.69^2 \times 150^3}{24 \times 8400^2} \\ &= 150 + .0438 \text{ feet.} \end{aligned}$$

at -10° F., 8400 pounds tension.

This represents a definite quantity of material in the span, and, as the quantity of material does not change (the strand being clamped at the points of support), the effects of temperature and tension changes can be found.

Assume that the tension is reduced to, say, zero, then from equation (2),

$$\begin{aligned} l &= l_0 + \frac{\Delta T l_0}{C.E} \\ &= 150.0438 - \frac{8400 \times 150.0438}{0.237 \times 26,000,000} \\ &= 150.0438 - 0.2045 \\ &= 149.8393 \text{ feet} \end{aligned}$$

at -10° F., zero tension.

This is less than the span, but that does not make any practical difference, as the reduction of the stress to zero is hypothetical.

Now, still considering the same quantity of material and assuming the stress is constant, 8400 pounds, let the temperature be 30° , 60° , and 90° F. respectively. The values of l are obtained from equation (1):

$$l = l_0 + l_0 (\Delta t. a)$$

So that, at 30°

$$\begin{aligned} l &= 150.0438 + 150.0438 (40 \times .0000064) \\ &= 150.0822 \text{ feet} \end{aligned}$$

and at 60°

$$\begin{aligned} l &= 150.0438 + 150.0438 (70 \times .0000064) \\ &= 150.1110 \text{ feet} \end{aligned}$$

while at 90°

$$\begin{aligned} l &= 150.0438 + 150.0438 (100 \times .0000064) \\ &= 150.1398 \text{ feet.} \end{aligned}$$

Since the elastic change in length due to temperature variations is independent of the temperature, there may now be plotted a series of "isothermal" lines, -10° , 30° , 60° , 90° tension *vs.* length for this quantity of strand. These lines will, of course, be parallel. On these "isothermal" lines may be plotted the lengths of parabola containing the same quantity of material, and loaded with any load w .

The normal load for the $\frac{5}{8}$ -inch strand with the track wires

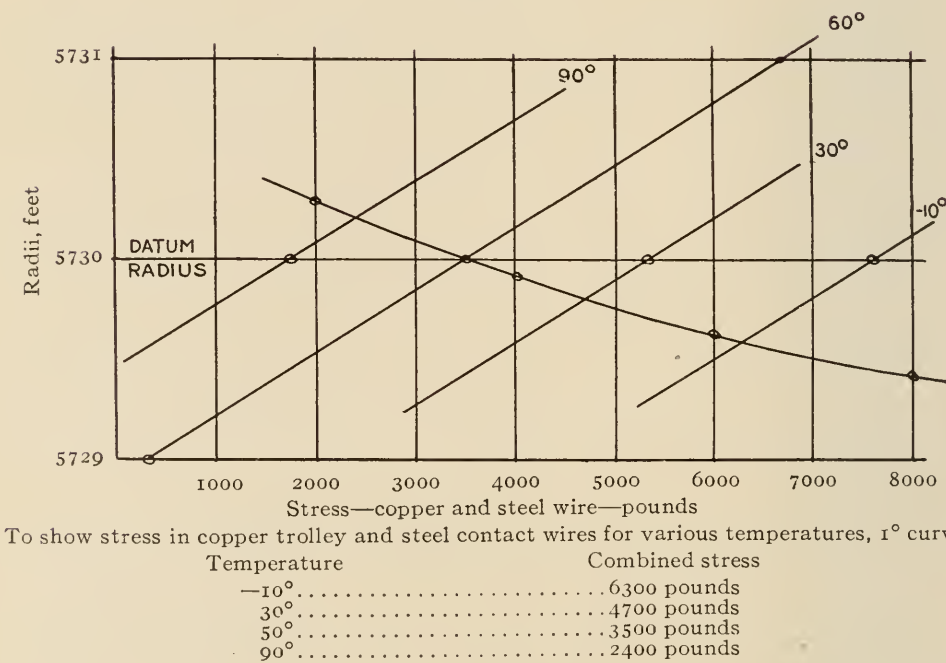
hanging from it is 2.185 pounds per foot (see Table I), and the length of a parabola under different tensions is given by equation (6) :

$$\begin{aligned} l &= d + \frac{w^2 d^3}{24 T^2} \\ &= 150 + \frac{2.185^2 \times 150^3}{24 T^2} \\ &= 150 + \frac{674000}{T^2} \end{aligned}$$

giving :

<i>T</i>	<i>l</i>
2000 pounds.....	150.168 feet
3000 pounds.....	150.075 feet
4000 pounds.....	150.042 feet
5000 pounds.....	150.027 feet
6000 pounds.....	150.019 feet
7000 pounds.....	150.014 feet
8000 pounds.....	150.011 feet

FIG. 8.



If this curve be superimposed on the other lines, the points of intersection indicate the tension that exists in the strand at those various temperatures with this particular loading (which is the normal load).

Another set of parabola lengths, showing the strand with only its own weight as load, may also be plotted. This latter load is

0.810 pound per foot (Table I). Using equation (6) again, we get

$$\begin{aligned} l &= d + \frac{w^2 d^3}{24 T^2} \\ &= 150 + \frac{0.810^2 \times 150^3}{24 T^2} \\ &= 150 + \frac{37610}{T^2} \end{aligned}$$

giving:	T	l
	1000 pounds.....	150.0376 feet
	2000 pounds.....	150.0094 feet
	3000 pounds.....	150.0042 feet
	4000 pounds.....	150.0021 feet
	5000 pounds.....	150.0015 feet
	6000 pounds.....	150.0011 feet

The intersections of this curve with the isothermal lines give the stress at these various temperatures of the strand with only its own weight, and this data may be used in pulling up the messenger (see Fig. 4).

Knowing the appropriate stresses at various temperatures, we can find sags for any span. Since a span length of 150 feet was taken as a basis, the results are not accurate for spans of other lengths, as the temperature effect is not the same, being greater for shorter spans, and *vice versa*. Nevertheless, as the error is not very great (when the variation in length of span is small), and since to take care of it would complicate the calculation considerably, this feature is ignored.

The corresponding hangers for all lengths of span are the same; that is, for instance, the six shortest hangers of a 200-foot span are the same as the six hangers of a 60-foot span.

The hangers are spaced approximately 10 feet apart. Thus, for spans containing an *even* number of hangers the lengths are different from those containing an *odd* number, and two sets of lengths are provided, one set (for “odd” spans) with one shortest hanger, and one set (for “even” spans) with two “shortest” hangers.

From the curve, Fig. 4, the stresses are:

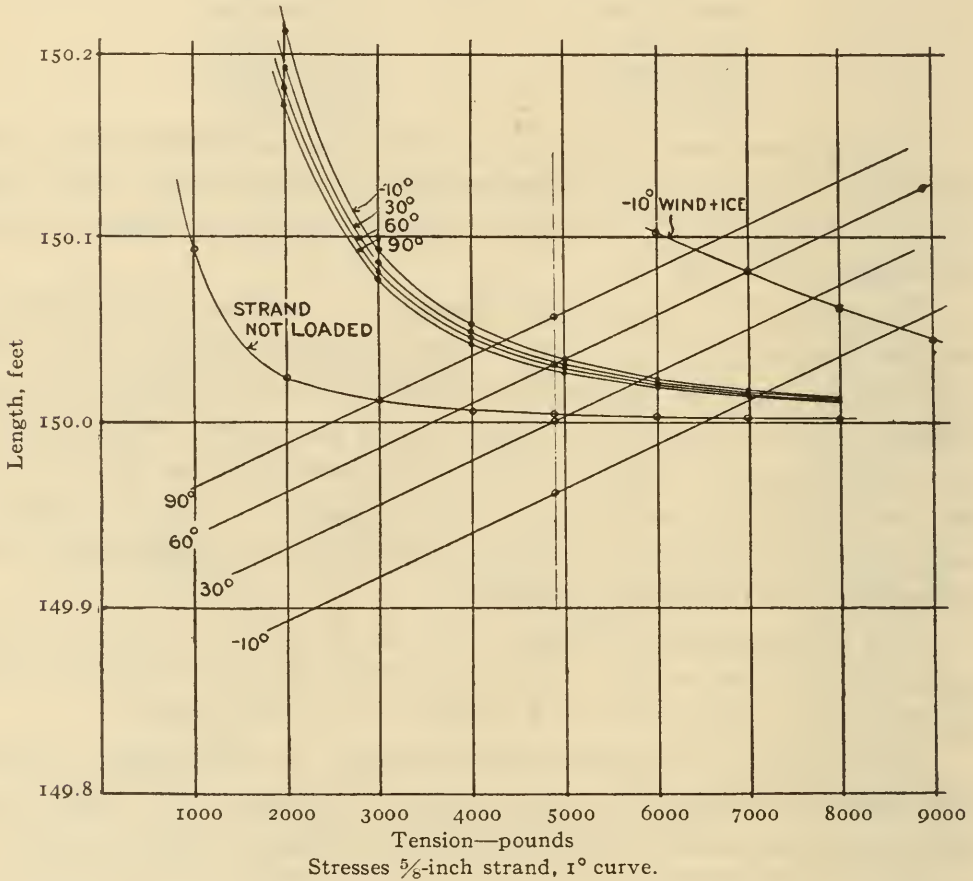
		-10° wind and ice	-10°	30°	60°	90°
Stress in pounds in 5/8-inch strand	Not loaded.....	—	6600	5100	4000	3000
	Normal load.....	8400	7100	5800	4900	4200

To find the sag for various spans at the different temperatures, equation (4) applies:

$$S = \frac{w d^2}{8 T}$$

the load per foot and the tensions at various temperatures being known. The values of sag for various spans, both for pulling up the strand and for finding the final position of the strand under load, are plotted in Fig. 19.

FIG. 9.



CURVE CONSTRUCTION.

As is indicated above, the trolley and contact wires lie in a smooth curve following the track curves. The hangers are, therefore, inclined at an angle which is the resultant of their weight and the horizontal pull of the trolley and contact wires.

The stresses on curves are found just as on tangents, there being only the added load due to the curve. All the loads are resolved into vertical and horizontal components, and the sags

are also resolved into vertical and horizontal components, the total deflection or sag of the messenger being the resultant.

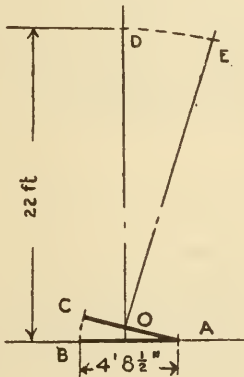
The tension of the trolley and contact wires causes the curve load, and this is found as follows: Assume a track curve making a complete semicircle (Fig. 5), the contact and trolley wires being pulled to coincide with this curve. There is a horizontal force acting on these wires of, say, w pounds per foot to keep them in position. Referring to Fig. 5, if

- T = Tension in wires, pounds.
- F = Horizontal force normal to wires, pounds.
- d = Span in feet.
- R = Radius of curve in feet.

On any element $R.d\rho$ the force acting on the wire is $w.R.d\rho$, and the component normal to the diameter would be

$$w. \sin \phi. d\rho = dF$$

FIG. 10.



Integrating between $\rho = 0$ and $\rho = \pi$, we get

$$\begin{aligned} F &= w.R \int_0^\pi w. \sin \phi. d\rho \\ &= w.R \left(-\cos \phi \right)_0^\pi \\ F_0 &= 2 w.R \text{ for entire semicircle. This is resisted} \\ &\quad \text{by the wire at each end of the semicircle, or} \\ &\quad \text{by the force } 2T. \text{ Thus} \\ 2 T &= 2 w.R \\ w &= \frac{T}{R} \dots \dots \dots (7) \end{aligned}$$

For a small arc in the circle subtending angle m symmetrical about centre line,

$$\begin{aligned} F &= 2 w.R. \cos m \\ \text{if } d &= 2 R. \cos m \\ &\text{(which it does nearly if } m \text{ is small).} \end{aligned}$$

Substituting

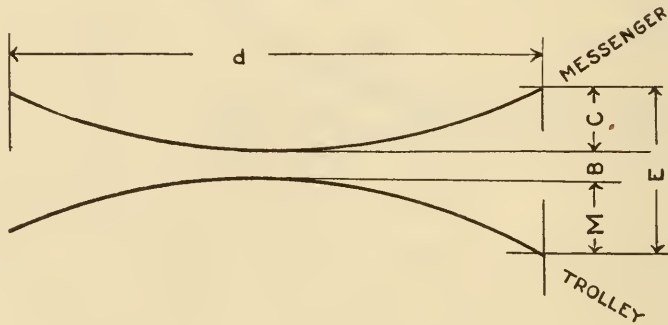
$$T = w.R$$

we get

$$\begin{aligned} F &= w.d \\ &= \frac{T.d}{R} \dots\dots\dots (8) \end{aligned}$$

It is interesting to note that it makes practically no difference in what shape the wires are pulled around a curve, whether in a smooth arc or in chords, the force required to keep them in position is the same, if the curve is not too sharp.

FIG. 11.



Suppose wires are pulled around curves in a series of chords FOD in Fig. 6. Two spans marked d are shown in this figure. The force required to keep the wire in position is OB , the tension in the wire being $OA = OC = T$. Parallelograms $FODH$ and $CBAO$ are similar, so

$$\frac{OB}{2OG} = \frac{OA}{OD}$$

but $OB = F$ and $OA = T$ (where F is the force required to pull the wires off in the proper position and T is the tension in the wires).

$$\begin{aligned} OG &= 6D \text{ (nearly)} \\ &= d \text{ (span)} \end{aligned}$$

therefore

$$\begin{aligned} OG &= R - \sqrt{R^2 - d^2} \\ &= OD \end{aligned}$$

Substituting

$$\frac{F}{2(R - \sqrt{R^2 - d^2})} = \frac{T}{D}$$

or

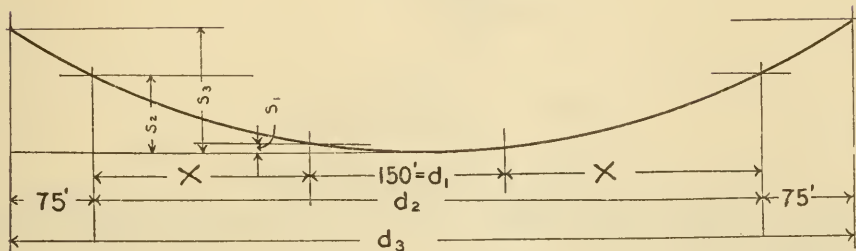
$$F = \frac{2T(R - \sqrt{R^2 - d^2})}{d}$$

Expand $\sqrt{R^2 - d^2}$ by binomial theorem

$$[(a + b)^n = a^n + na^{n-1}b + \dots\dots\dots]$$

$$\begin{aligned} \sqrt{R^2 - d^2} &= R + \frac{1}{2}R^{-1}(-d^2) + \dots\dots\dots \\ &\text{(neglect rest of terms)} \\ &= R - \frac{d^2}{2R} \end{aligned}$$

FIG. 12.



Substitute in above

$$\begin{aligned} F &= \frac{2T(R - R - \frac{d^2}{2R})}{d} \\ &= \frac{2Td}{R} \text{ for both spans} \end{aligned}$$

or

$$F = \frac{Td}{R} \dots\dots\dots(9)$$

which is similar to equation (8).

This identity is useful in finding forces acting on catenary bridges.

The tension in the copper and steel wires on curves is not the same as on tangents at all temperatures, because the inclination of the hangers varies with temperature variations, and as the inclination increases the radius of the circumference on which the wires lie is reduced, and the tension therefore varies less than on tangents.

There is very little taking up or paying out of wire from tangents to curves, and *vice versa*, because the hangers are rigidly

fastened to the $\frac{5}{8}$ -inch messenger and the copper wire on tangents and to the $\frac{5}{8}$ -inch messenger and steel wire on curves, and the $\frac{5}{8}$ -inch messenger is held tightly at the insulators.

Assume a stress of 2100 pounds in the steel and 1400 pounds in the copper wires at 60° F. The radius of a 1° curve is 5730 feet, and we can consider the wires running along a circumference of that radius. Sum of stresses = 3500 pounds. Now suppose the wires move out so they lie on a curve of 5731 feet radius. The length of a 150-foot arc will increase

$$\frac{5730}{1} = \frac{150}{x} = 0.0262 \text{ feet}$$

and will now be 150.0262 feet. Transposing equation (2), we have

$$l - l_0 = \frac{\Delta T \cdot l_0}{EC}$$

or

$$0.0262 = \frac{150 \Delta T}{23,250,000 \times 332}$$

$$\Delta T = 3190 \text{ pounds increase.}$$

(In the above, the value of E is the mean of E for steel = 29,000,000 and E for copper = 17,500,000; the value of C is 2×0.166 .)

If the radius is reduced to 5729 feet, the reduction in stress would be practically the same quantity, 3190 pounds; *i.e.*,

Radius 5729 feet.	Tension 3500 - 3190 =	310 pounds
Radius 5730 feet.	Tension	= 3500 pounds
Radius 5731 feet.	Tension 3500 + 3190 =	6690 pounds

assuming temperature constant, 60° F.

These values may be plotted, stress *vs.* radius, as an "isothermal" line. The line will be practically straight (Fig. 8).

If the temperature becomes -10° , 30° , and 90° respectively, it may be assumed that the wires lie on a curve of 5730 feet radius at each of these temperatures, the stress of the two wires being, in each case:

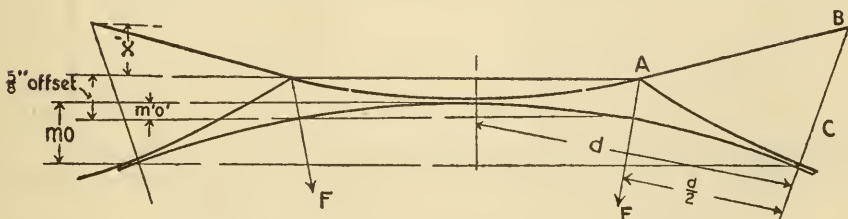
Temperature	-10°	30°	90°
Stress, pounds. . . {	3300	2200	570
	4300	3100	1220
	7600	5300	1790

These values may be plotted as “isothermal” lines parallel to the 60° line (Fig. 8).

The length of wire corresponding to various inclinations of hanger rod is found thus: The vertical component is 0.641 (copper) + 0.558 (steel) + 0.177 (hanger) [see Table I] = 1.376 pounds per foot, and is constant. The horizontal component is the value of w in the equation $w = \frac{T}{R}$ (equation 7). Call this horizontal component x , and let β be the inclination of the hanger, z the length of the longest hanger (= 1.83 feet \pm), and y the horizontal displacement of the wires. Then, referring to Fig. 7,

$$\begin{aligned} \tan \beta &= \frac{x}{1.376} \\ y &= z \sin \beta \\ &= 1.83 \sin \beta \end{aligned}$$

FIG. 13.



If various values of the stress are assumed, corresponding values of x calculated from equation (7) and of $\tan \beta$ and y from the above, the distances of wires from datum point at 60° F. in Table II are obtained.

TABLE II.

Assumed stress in pounds	Value of x in pounds from equation (7), $R=5730$	$\tan \beta$	$\sin \beta$	y	Distance of wires from datum (60° F.)
2000	0.349	0.254	0.246	0.450	0.294 outside datum
3500	0.611	0.444	0.406	0.744	0.086 inside
4000	0.699	0.508	0.453	0.830	0.367 inside
6000	1.047	0.761	0.606	1.111	0.558 inside
8000	1.396	1.015	0.712	1.302	

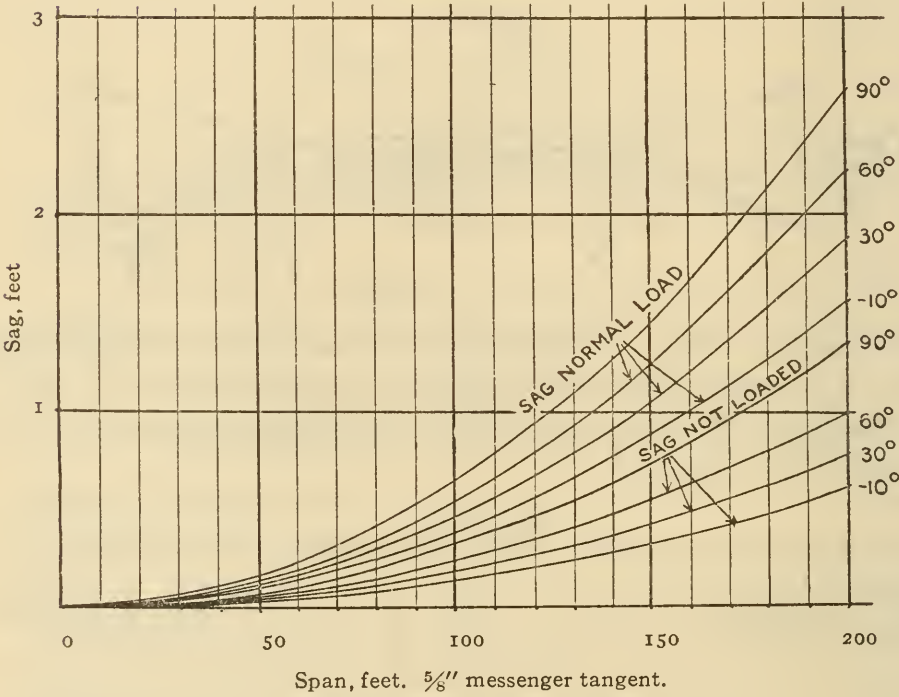
If the stress of 3500 pounds is considered the basis of calculations, the location of the wires at this tension is the datum point, and the distance away from that point (5730 feet radius)

may be plotted for the various tensions, over the “isothermal” lines, the intersections being the tension of the copper and steel wires combined for the corresponding temperature (Fig. 8). These stresses of the copper and steel grooved wires give the horizontal load components on the 5/8-inch messenger:

$$w = \frac{T}{R} \dots\dots\dots (7)$$

	-10°	30°	60°	90°
<i>T</i>	6300	4700	3500	2400
<i>R</i>	5730	5730	5730	5730
<i>w</i>	1.100	0.821	0.611	0.418

FIG. 14.



The vertical load, as on tangent, is 2.185 pounds per foot, so that the resultant loads are:

- 10°.....2.442 pounds per foot
- 30°.....2.331 pounds per foot
- 60°.....2.270 pounds per foot
- 90°.....2.220 pounds per foot

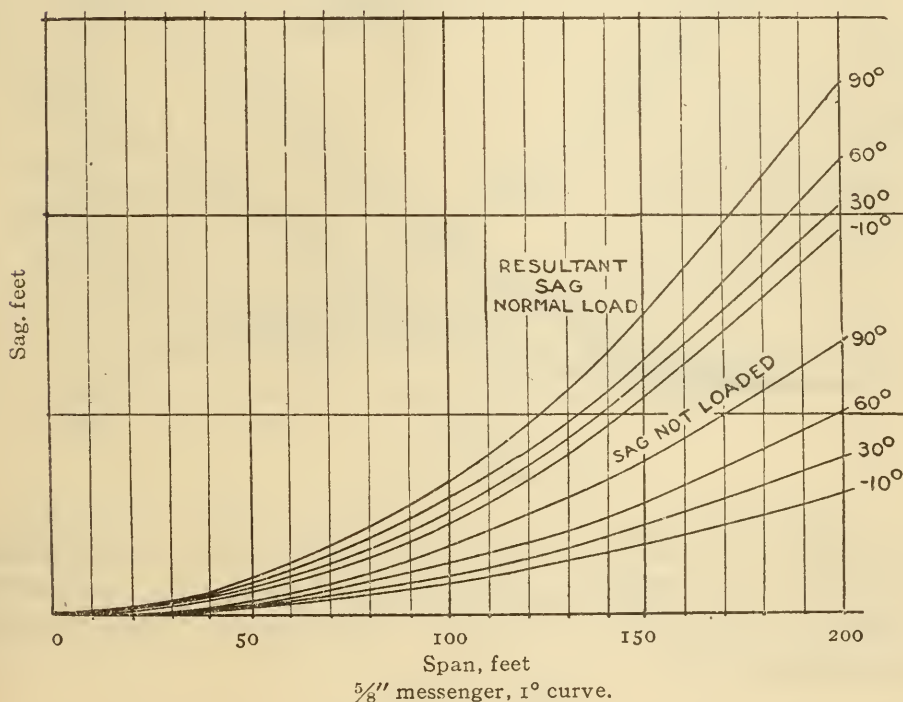
Assume stress of 4900 pounds in the $\frac{5}{8}$ -inch messenger at 60° F. (the stress on the whole system, tangent and curves, is 4900 pounds at 60° F.), then the sag s is given by equation (4):

$$\begin{aligned} s &= \frac{wd^2}{8T} \\ &= \frac{2.27 \times 150^2}{8 \times 4900} \\ &= 1.30 \text{ feet.} \end{aligned}$$

Now to find the length of material in this span, use equation (5),

$$\begin{aligned} l &= d + \frac{8s^2}{3d} \\ &= 150 + \frac{8}{3} \cdot \frac{1.30^2}{150} \\ &= 150.0301 \text{ feet.} \end{aligned}$$

FIG. 15.



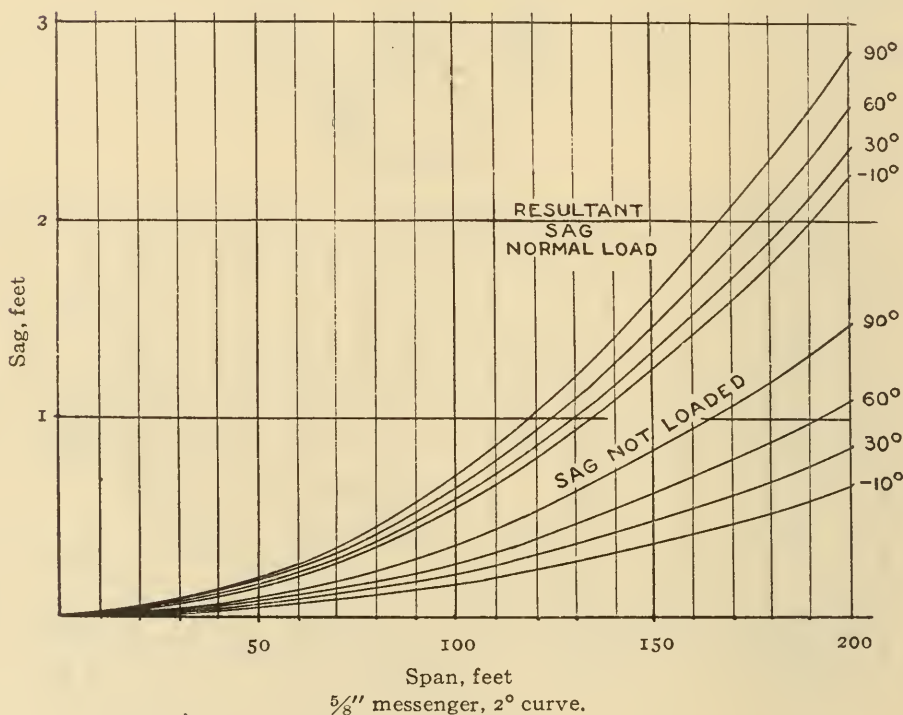
Assume tension raised to, say, 8900 pounds, temperature remaining 60° F., from equation (2)

$$\begin{aligned} l &= l_0 + \frac{\Delta T \cdot l_0}{CE} \\ &= 150.0301 + \frac{4000 \times 150.0301}{0.237 \times 26,000,000} \\ &= 150.1276 \text{ feet.} \end{aligned}$$

Assume temperature changes to -10° , 30° , 90° , respectively, the tension remaining at 4900 pounds, from equation (1)

$$\begin{aligned}
 l &= l_0 + l_0 \Delta t \alpha \\
 &= 150.0301 + 150.0301 (.0000064 \Delta t) \\
 &= 150.0301 + 0.00902 \Delta t \\
 \text{so that, at } -10^\circ \quad l &= 150.0301 - 0.0673 = 149.9628 \text{ feet} \\
 \text{at } 30^\circ \quad l &= 150.0301 - 0.0282 = 150.0019 \text{ feet} \\
 \text{at } 90^\circ \quad l &= 150.0301 + 0.0282 = 150.0583 \text{ feet}
 \end{aligned}$$

FIG. 16.



We have a variable horizontal load for various temperatures, so a separate curve must be plotted for each load. For the resultant loads at -10° , 30° , 60° , and 90° , the values of l are obtained from equation (6),

$$\begin{aligned}
 l &= d + \frac{w^2 d^3}{24 T^2} \\
 &= 150 + 140600 \frac{w^2}{T^2}
 \end{aligned}$$

so that at -10° , when resultant load = 2.442 pounds per foot,

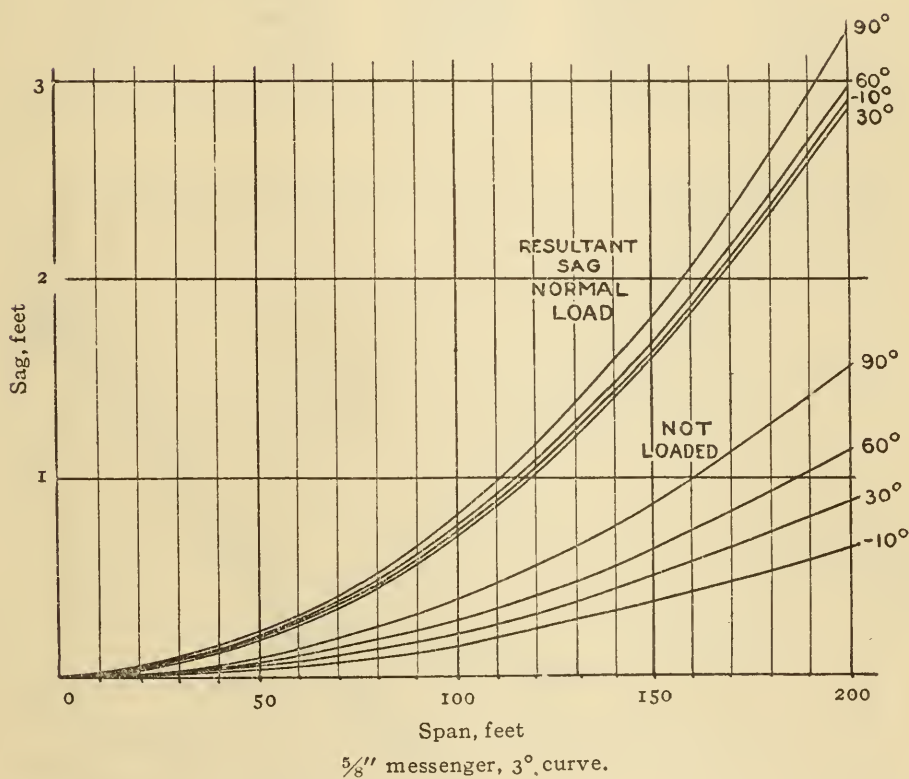
$$\begin{aligned}
 l &= 150 + 140600 \frac{2.442^2}{T^2} \\
 &= 150 + \frac{842000}{T^2}
 \end{aligned}$$

and at 30° , when resultant load = 2.331 pounds per foot,

$$l = 150 + 140600 \frac{2.331^2}{T^2}$$

$$= 150 + \frac{767000}{T^2}$$

FIG. 17.



and at 60° , when resultant load = 2.270 pounds per foot,

$$l = 150 + 140600 \frac{2.270^2}{T^2}$$

$$= 150 + \frac{725000}{T^2}$$

and at 90° , when resultant load = 2.220 pounds per foot,

$$l = 150 + 140600 \frac{2.220^2}{T^2}$$

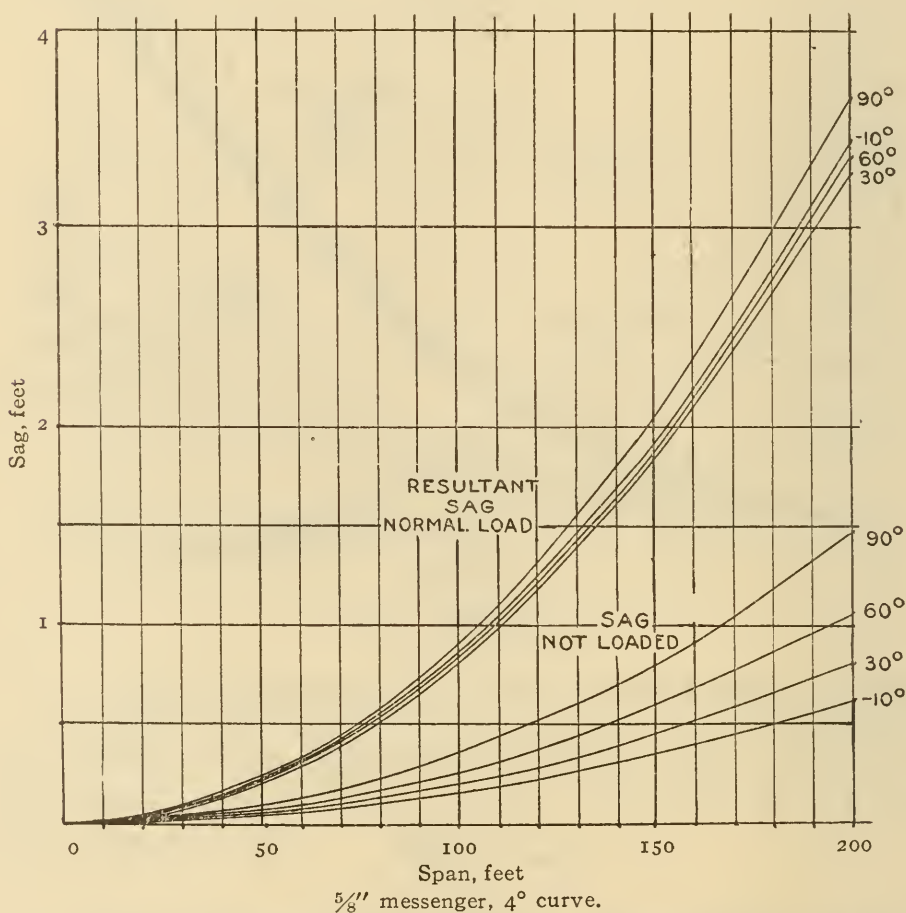
$$= 150 + \frac{695000}{T^2}$$

Substituting the various values of T , we get the values of l in Table III.

TABLE III.

T	l_{-10}	l_{30}	l_{60}	l_{90}
2000	150.211	150.192	150.181	150.174
3000	150.0935	150.0853	150.0805	150.0772
4000	150.0526	150.0479	150.0454	150.0434
5000	150.0336	150.0306	150.0290	150.0278
6000	150.0234	150.0213	150.0202	150.0193
7000	150.0172	150.0156	150.0148	150.0142
8000	150.0132	150.0120	150.0113	150.0109

FIG. 18.

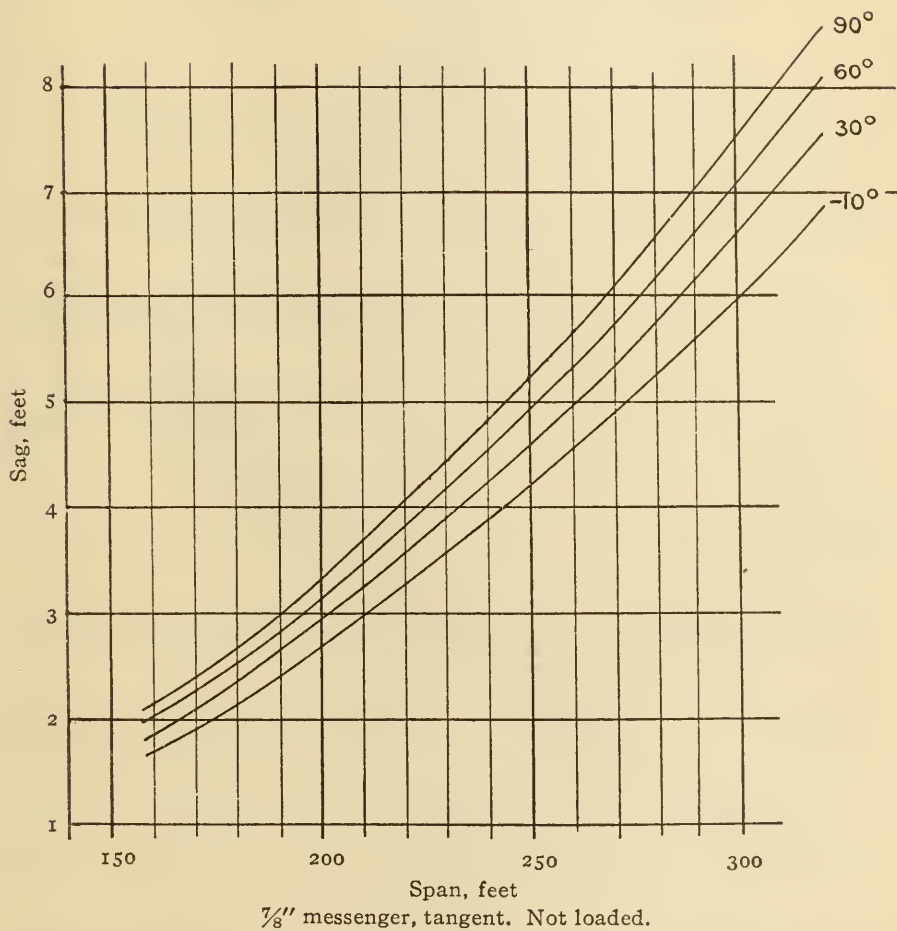


To find the stresses at various temperatures with no load except the weight of the strand itself, which is 0.810 pound per foot:

$$\begin{aligned}
 l &= 150 + \frac{0.810 \times 150^3}{24T^2} \\
 &= 150 + \frac{92500}{T^2}
 \end{aligned}$$

<i>T</i>	<i>l</i>
1000.....	150.0925
2000.....	150.0231
3000.....	150.0103
4000.....	150.0058
5000.....	150.0037
6000.....	150.0025
7000.....	150.0019
8000.....	150.0014

FIG. 19.



The maximum load on a 1° curve occurs with ice and wind. The wind acting on the trolley and contact wires, however, tends to throw slack into them and reduce their tension, so that item may be omitted.

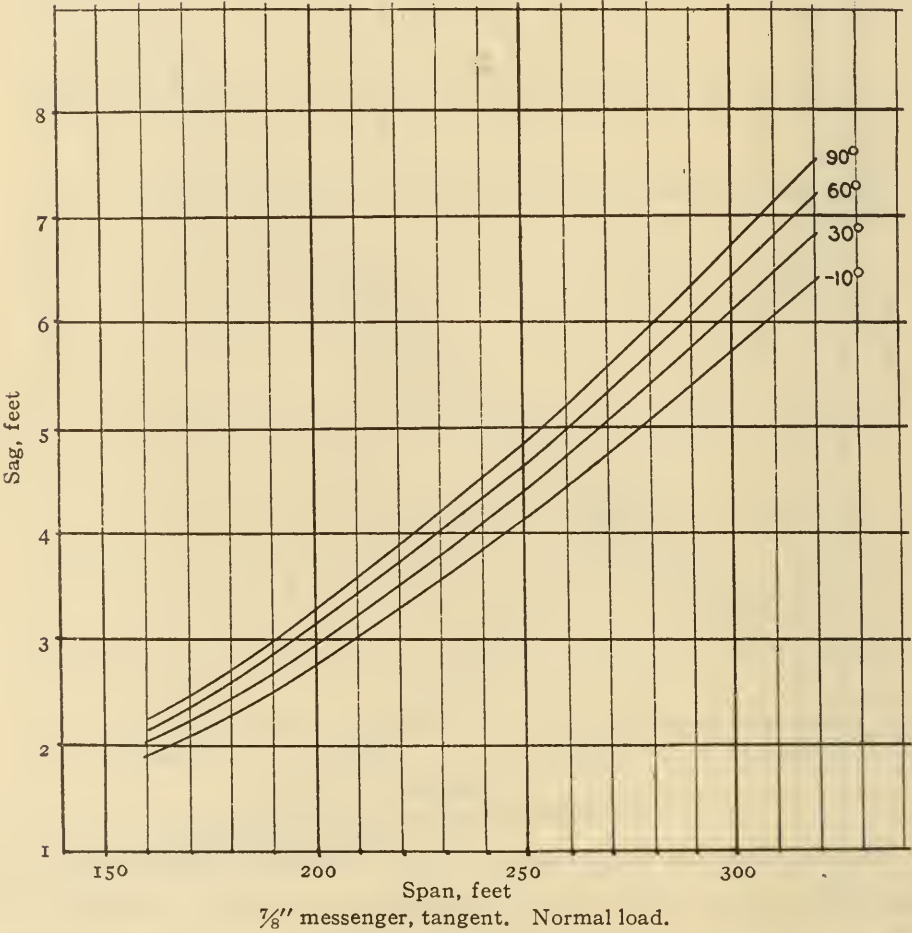
	Vertical	Horizontal
Load.....	4.159 pounds per foot.	
Wind load (as above).....		0.845 pounds per foot
Curve load, -10° F.....		2.442 pounds per foot
	4.159	3.287
Resultant = 5.30 pounds per foot.		

Plot another curve for this load, as before, to find maximum load.

$$l = 150 + \frac{5.30^2 \times 150^3}{24T^2}$$
$$= 150 + \frac{3975000}{T^2}$$

<i>T</i>	<i>l</i>
6000.....	150.101
7000.....	150.0812
8000.....	150.0622
9000.....	150.0490

FIG. 20.



From the curves plotted (Fig. 9) the stresses for the strand, under normal curve loads, are:

	-10° wind and ice	-10°	30°	60°	90°
Not loaded...	—	6600	5000	3900	3000
Normal load..	8700	7200	5800	4900	4200

FIG. 21.

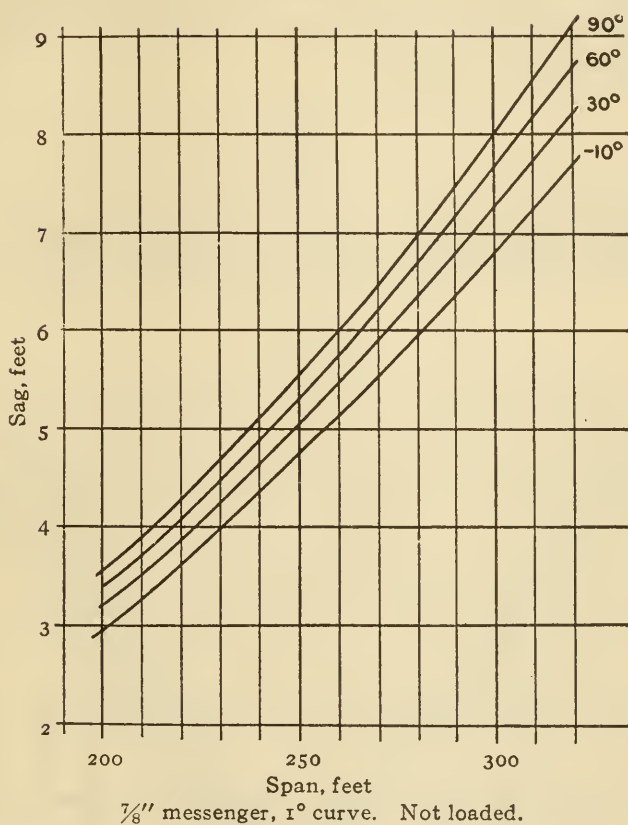
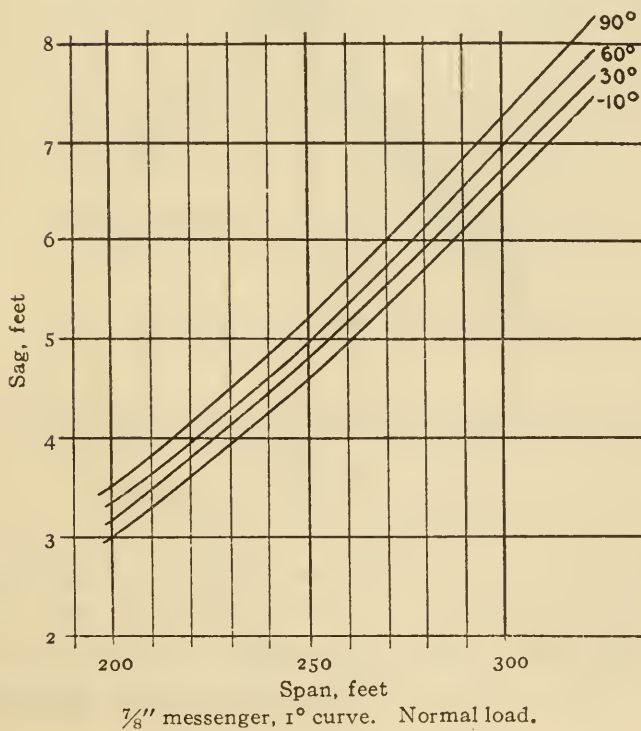


FIG. 22.



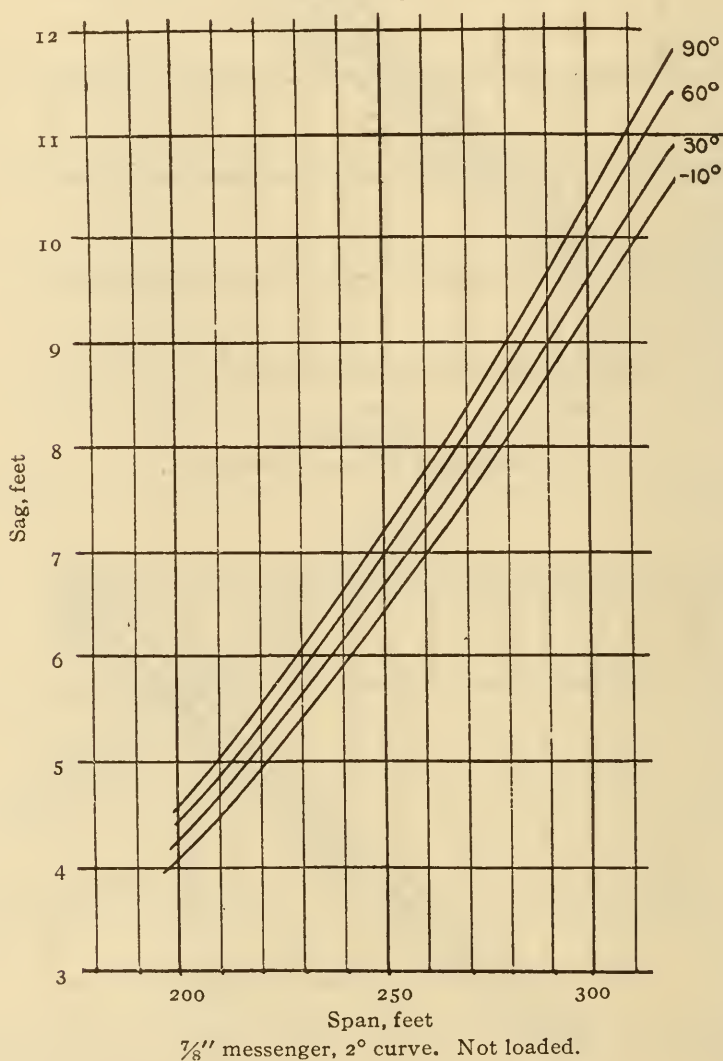
Maximum stress with wind and ice, 8700 pounds.

From these stresses we may get the sags for various temperatures as before (see Table I).

$$s = \frac{wd^2}{8T}$$

The hangers are forged steel, and are arranged so the copper and steel wires shall be as nearly as possible in the same vertical

FIG. 23.

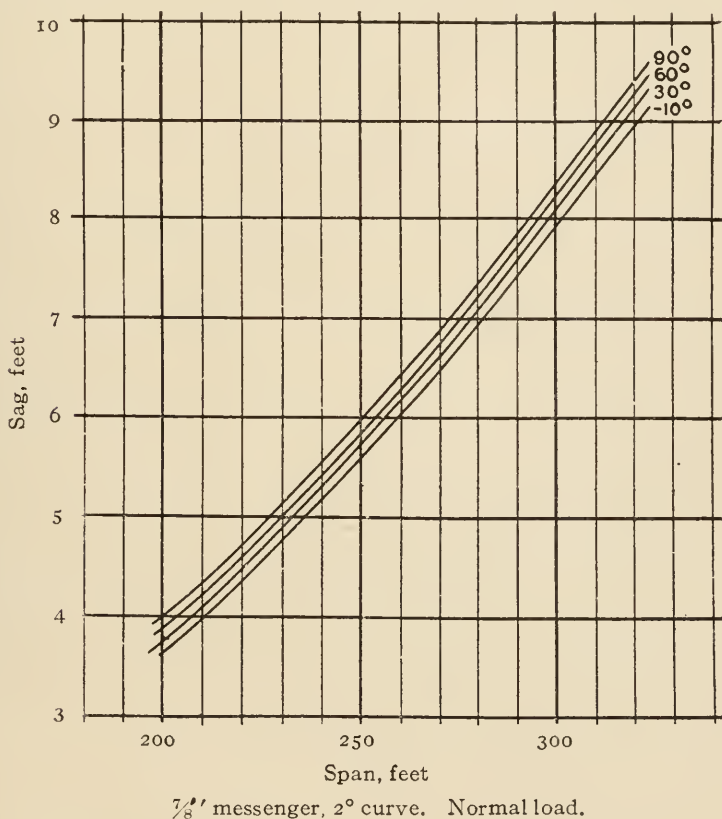


plane. Therefore, the average inclination of the hangers must be found. The inclination is the resultant of the curve pull of the wires (horizontal) and the weight of the wires and hangers (vertical). This vertical load is different in different portions

of the span—the hangers at the ends being longer than those near the centre—so the inclination is slightly greater near the centre. This difference, however, is small, and a mean is easily found. For the same reason the length of hangers is slightly less near the ends of the spans than the theoretical length.

In order that the trolley shall be at the centre of the collecting shoe on curves, the catenary supports must be located on the outside of the curve, so as to give the messenger a horizontal component to balance that of the track wires.

FIG. 24.



The superelevation of the outer rail of the track throws the collector shoe towards the inside of the curve as follows:

In Fig. 10, triangles OED and ABC are similar. Therefore, if D represents the trolley wire, the clearance being 22 feet, and the gauge 4 feet $8\frac{1}{2}$ inches = 4.716 feet,

$$\frac{DE}{CB} = \frac{22}{4.716} = 4.65$$

that is, each inch of superelevation throws the collector shoe over about 4.65 inches, and this must be subtracted from the distance the insulator must be offset toward the outside of the curve.

The other elements of the offset calculations are (Fig. 11):

M = Mid-ordinate of track curve for span.

B = Horizontal projection of shortest hanger.

C = Horizontal projection of sag of messenger.

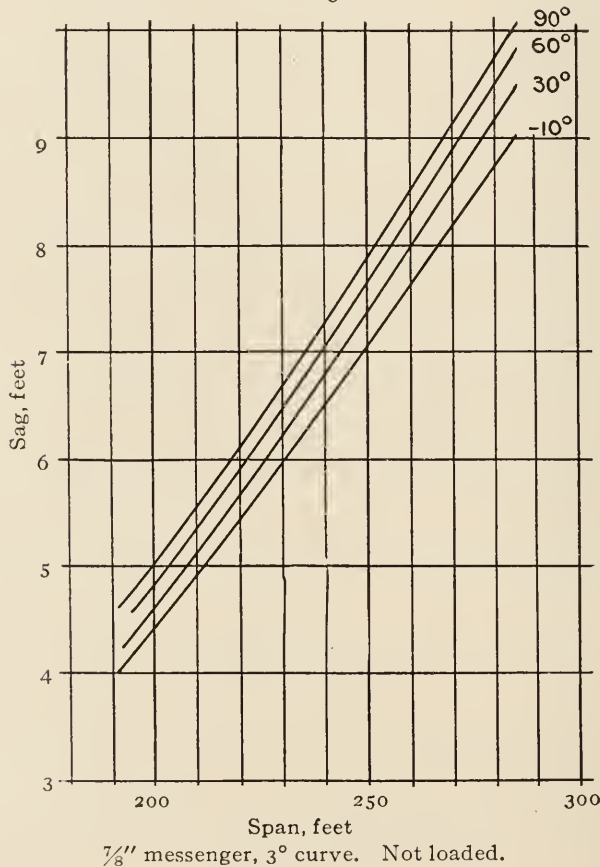
E = Total offset distance — $M + B + C$.

The distance B is a constant for 1° curve hangers 0.2 foot.

The horizontal component of the sag is found from the horizontal load $w = 0.611$ pound per foot, and the tension 4900 pounds.

$$s = \frac{wd^2}{8T}$$

FIG. 25.



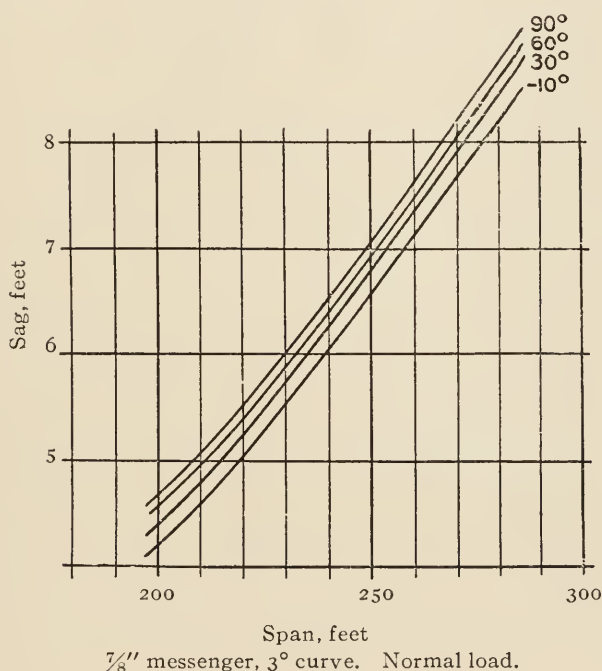
The computations for 2° , 3° , and 4° curves are made in the same way as 1° curve, except that the assumed span for 3° curve is 130 feet and 4° curve is 100 feet, instead of 150 feet.

CALCULATIONS FOR SEVEN-EIGHTH-INCH STRAND.

The calculations for the $\frac{7}{8}$ -inch strand are similar to those for the $\frac{5}{8}$ -inch strand, but the $\frac{7}{8}$ -inch catenary is broken at each *I*-beam support (Fig. 1). For purposes of computing the sags, etc., the weight of the *I*-beams, insulators, track catenaries, etc., is considered as replaced by a length of $\frac{7}{8}$ -inch strands of equal weight (length X in Fig. 12). Thus the $\frac{7}{8}$ -inch strand would lie in a smooth curve whose length would be $300 + 2X$ feet and the sag of which would be $s_3 - s_2 + s_1$ (see Fig. 12).

The computation of stress for various temperatures is made like that of $\frac{5}{8}$ -inch strand.

FIG. 26.



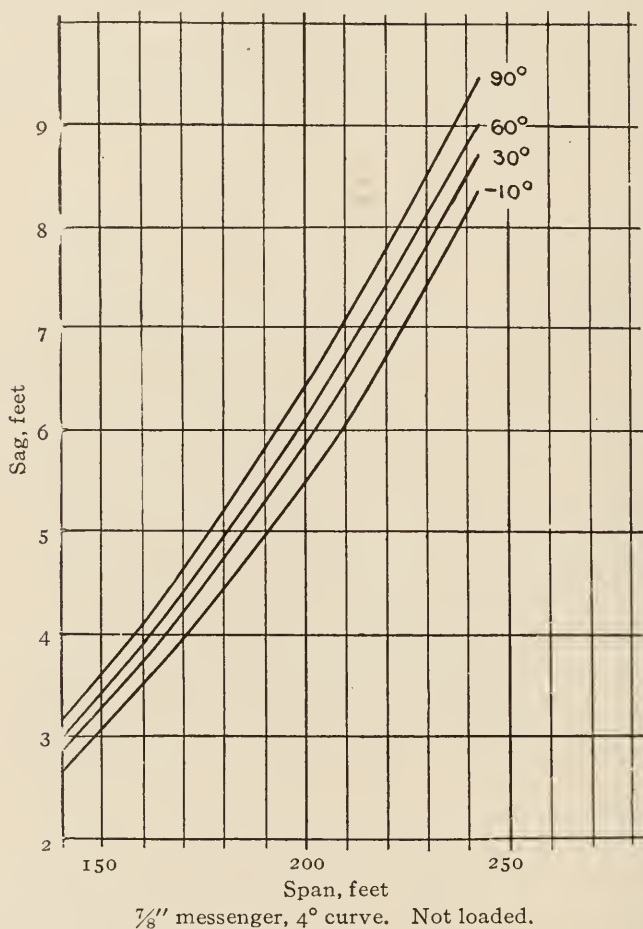
The ratio of the weight of the entire catenary system to the stress in the $\frac{7}{8}$ -inch messenger is so large that the difference between the horizontal component of the stress and the total stress is not negligible. The total stress is the resultant of the weight and horizontal tension. The $\frac{7}{8}$ -inch strand is clamped to the catenary bridges by malleable iron saddles, so that once strung the quantity of strand in a given span cannot change.

In the case of the short spans, the *I*-beam is not clamped close to the $\frac{7}{8}$ -inch strand, because the resulting small sag would raise the trolley too high. Hangers of $2\frac{1}{2} \times 2\frac{1}{2}$ -inch galvanized angle

iron were inserted between the *I*-beam and $\frac{7}{8}$ -inch strand to bring the *I*-beam to the correct height, so standard hangers could be used.

The horizontal component of the sag on curves is found as follows: The entire curve load is concentrated at the *I*-beam; let this be F . This is caused by the trolley wires and the $\frac{5}{8}$ -inch

FIG. 27.



strand (Fig. 2 stress in wires = 3500 pounds; Fig. 4 stress in $\frac{5}{8}$ -inch strand = 4900 pounds), these figures holding for all curves at 60° F.

The stresses in the wires and messenger may be added together [equation (8)].

$$F = \frac{Td}{R}$$

$$= \frac{8400d}{R}$$

FIG. 28.

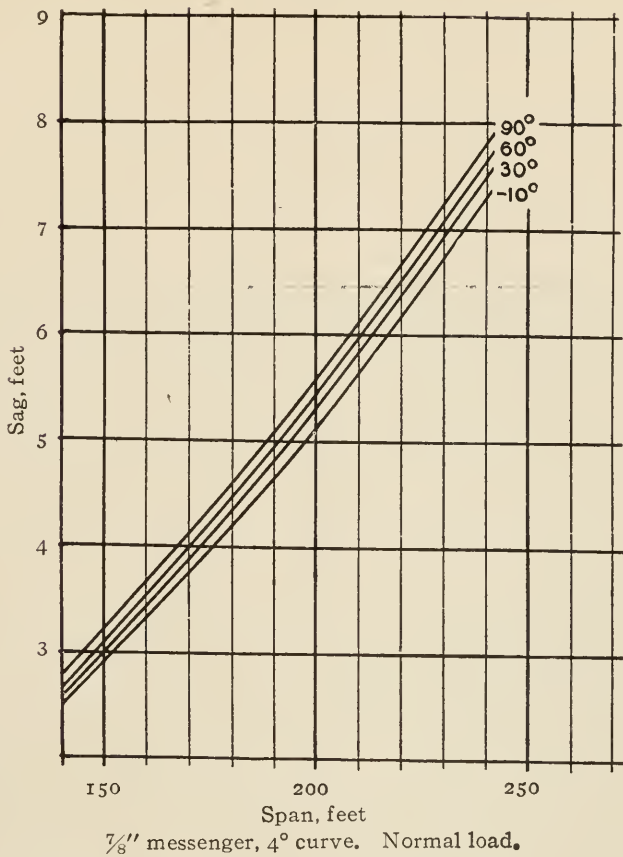
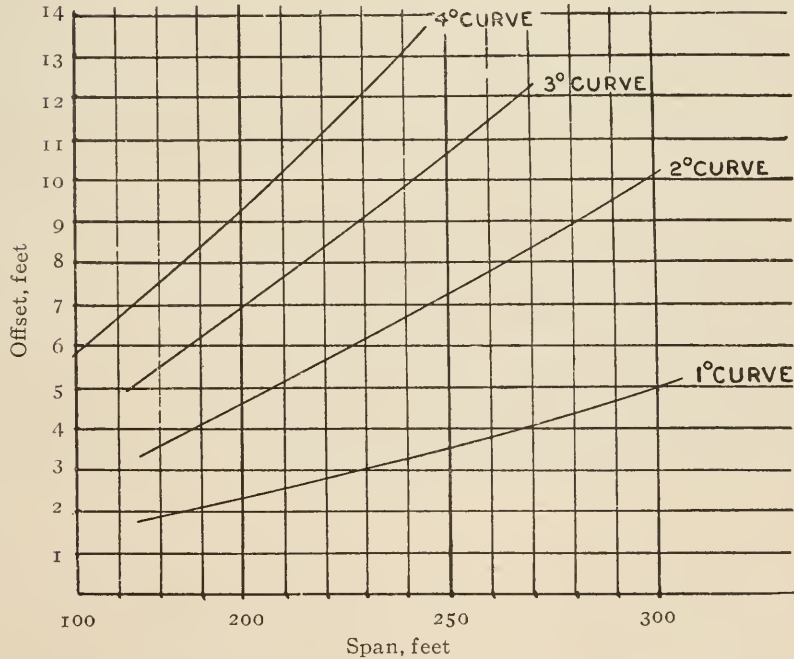


FIG. 29.



Offsets of saddles for $\frac{3}{4}$ -inch strand from centre line of track toward outside of curve.
(Correction for superelevation of outer rail to be subtracted.)

The horizontal component of the tension in the $\frac{7}{8}$ -inch strand is 7180 pounds at 60° .

From Fig. 13,

$$\frac{F}{7180} = \frac{x'}{d} \quad (\text{nearly})$$

2



30 curve. Showing also spacer hangers between *I*-beam and $\frac{7}{8}$ " strand where spans are less than 300 feet.

Substituting

$$F = \frac{8400d}{R}$$

$$\frac{d^2}{2} \times \frac{8400}{7180} = x'$$

$$x' = \frac{0.585d^2}{R}$$

The offset (exclusive of superelevation) is $mo - m'o' + \frac{5}{8}$ offset + x' .

TABLE IV.
Stresses, in Pounds, in 5/8-inch Messenger, Various Temperatures.

Temperature	-10°	30°	60°	90°
Tangent:				
Not loaded.....	6600	5100	4000	3000
Normal load...	7100	5800	4900	4200
1° curve:				
Not loaded.....	6600	5000	3900	3000
Normal load...	7200	5800	4900	4200
2° curve:				
Not loaded.....	6300	4800	3700	2700
Normal load...	7300	5800	4900	4200
3° curve:				
Not loaded.....	6200	4700	3600	2600
Normal load...	7600	6000	4900	4000
4° curve:				
Not loaded.....	6500	5000	3900	2800
Normal load...	7700	6100	4900	3900



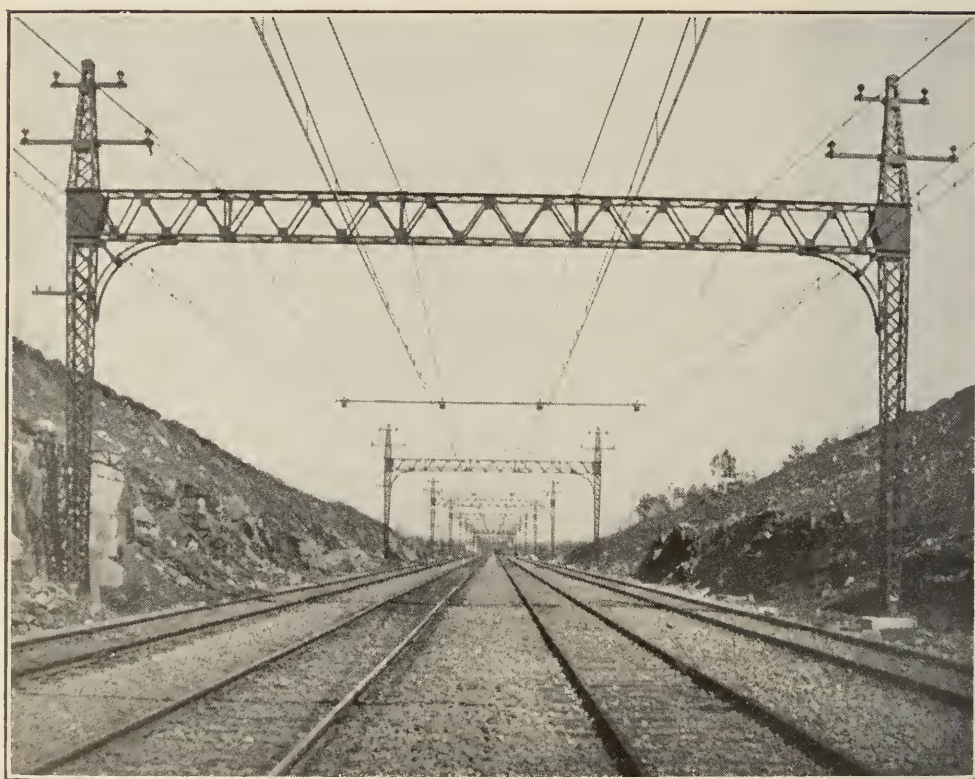
Tangent construction.

Average inclination of hanger from vertical:

Tangent.....	0
1° curve.....	28°
2° curve.....	48°
3° curve.....	58°
4° curve.....	63°

TABLE V.
Stresses, in Pounds, in $\frac{7}{8}$ -inch Strand, Various Temperatures.

Temperature	- 10°	30°	60°	90°
Tangent:				
No load	3200	2900	2700	2550
Normal load . . .	8500	8000	7550	7200
1° curve:				
No load	2850	2650	2500	2400
Normal load . . .	9200	8200	7550	7000
2° curve:				
No load	3000	2000	1900	1850
Normal load . . .	10100	8500	7550	6850
3° curve:				
No load	2000	1800	1750	1700
Normal load . . .	11500	9150	7550	6800
4° curve:				
No load	1550	1450	1400	1300
Normal load . . .	11600	9150	7550	6400



Tangent construction.

MAXIMUM LOAD DUE TO CATENARY CONSTRUCTION ON BRIDGES.

Three general types of bridges were used, as follows:

- (a) "Tangent," for tangent track only.
- (b) "1° curve," for curves up to 1° inclusive.
- (c) "4° curve," for all curves over 1°—with pull-off for curves over 4°.

The total vertical load is the sum of the loads in column 6, Table I, and is 6.711 pounds per foot, while the total wind load is the sum of the loads in column 8, and is 3000 pounds per foot.



4° curve.

The weight of the *I*-beam, ice-coated, is 105 pounds per track, and of the insulators and clamps is taken as 40 pounds per track. The *I*-beam and insulator wind load is taken as 10 pounds per track. So that:

For 300-foot span

$$\text{Vertical load} = 6.711 \times 300 + 105 \times 2 + 40 \times 2 = 2300 \text{ pounds per track.}$$

$$\text{Wind load (horizontal)} = 3.000 \times 300 + 10 \times 2 = 920 \text{ pounds per track.}$$

For 260-foot span

Vertical load = $6.711 \times 260 + 102 \times 2 + 40 \times 2 = 2030$ pounds per track

Wind load (horizontal) = $3.000 \times 260 + 10 \times 2 = 800$ pounds per track

and for 200-foot span

Vertical load = $6.711 \times 200 + 105 \times 2 + 40 \times 2 = 1630$ pounds per track.

Wind load (horizontal) = $3.000 \times 200 + 10 \times 2 = 620$ pounds per track.

The curve pulls are obtained from equation (8) :

$$F = \frac{Td}{R}$$

For $\frac{5}{8}$ -inch strand, $T = 9000$ pounds, and for $\frac{7}{8}$ -inch strand, $T = 18,000$ pounds. For the track wires, $T = 7600$ pounds. Therefore total $T = 34,600$ pounds.

The radius of 1° curve is 5730 feet; of 2° curve, 2865 feet; of 3° curve, 1910 feet, and of 4° curve, 1432 feet.

Hence :

For 1° curve

$$F = \frac{34600 \times 300}{5730} = 1810 \text{ pounds.}$$

For 2° curve

$$F = \frac{34600 \times 300}{2865} = 3620 \text{ pounds.}$$

For 3° curve

$$F = \frac{34600 \times 260}{1910} = 4710 \text{ pounds.}$$

For 4° curve

$$F = \frac{34600 \times 200}{1432} = 4840 \text{ pounds.}$$

Adding these curve pulls to the horizontal wind pulls above, we get the total horizontal loads, as follows :

For 1° curve.....	2730 pounds.
For 2° curve.....	4540 pounds.
For 3° curve.....	5510 pounds.
For 4° curve.....	5460 pounds.

The load of the feeders and the wind load of the structure itself are added to the above loads in designing the steel bents.

SOME RECENT ADVANCES IN PHOTOGRAPHY.*

BY

HENRY LEFFMANN, M.D., Ph.D.,

Member of the Institute.

ALTHOUGH for some years past the labors of many expert photographers have been largely directed to the so-called "artistic" side of photography, the purely technical and scientific sides have not been wholly neglected, and an inspection of the current journals and recent books will show many interesting results. The basic procedures for development, fixing, and toning have suffered but little change during many years. The competitive spirit has led to the introduction of many new developers, but most of these are minor modifications of the original forms, especially as regards the benzene derivatives, and in some cases the change is in name only. A conspicuous instance of the latter is in the use by the Lumière Company of the terms "quinomet" and "metoquinone" in their formula for color-plate work, the information at hand indicating that the names refer to the same substances and that this is merely an intimate mixture of metol and hydroquinone.

Probably the most important, at least the most generally exploited, advance in procedure in this field is color-photography. It is curious to note that in the first edition of his work on methods of photography M. Carey Lea stated that, in his opinion, color-photography was impossible, and he gave his reasons for this view. Not long after he modified his view, in consequence of the results of research, so far as to admit the possibility of such photography. He would surely be interested in some of the plates made to-day by the several processes that are extensively employed, and yet he could truly say that the results obtained by the Lumière, Dufay, and Paget plates are not really "color-photography," but colored photographs in which the hand of the artist has been substituted by ingenious automatic processes.

One of the latest applicants for favor in this line is the Paget

* Abstract of remarks made at the meeting of the Section of Photography and Microscopy, held October 15, 1914.

plate. This utilizes a color screen involving the same principle as the older methods,—that is, an even distribution of the three colors,—but in the Paget plate this screen is detachable and hence may be used for many plates. Moreover, the reversion of the image as followed by the older methods is substituted by using the plate as a negative, and attaching a viewing screen to a positive made in the usual manner. Paget screens are much more transparent than Lumière screens, and hence more satisfactory for lantern demonstration; on the other hand, they are much coarser, and a considerable magnification, as when a slide is projected on large extent, shows the individual colors and destroys the illusion. The total cost of a complete Paget lantern slide is slightly higher than that of a Lumière, but if the operator has a considerable proportion of failures, Paget methods are more economical. In sizes of the individual color areas the Paget screens agree closely with those of the Dufay and Thames plate (the latter is now out of the market).

It is well known to working photographers that the Lumière process employs the principle of reversion of image, as the transparency obtained by fixing after first development shows all colors complementary. Working with the color-plates suggested to me to try some of the reversal processes with ordinary plates,—that is, to obtain positives by one exposure. In the early days of negative making, the so-called wet plates, the possibility of direct positives was investigated and several methods were devised. These can be applied to the ordinary dry plates with much success, and, although such procedures are of no great practical value or wide application, they afford an interesting field for experiment by amateurs.

My experience has been principally with the following method:

Good exposure and good development are given, the developer is washed off and the plate stood, coated side outward, in a developing dish of black material (or the plate is backed by black paper), and several inches of magnesium ribbon are burned a few inches from it. The silver deposit acts as a negative, and the unchanged silver compounds are light-struck. The plate is then immersed in a solution of potassium dichromate and sulphuric acid, such as is used in reversing Lumière color-plates, until the image has practically disappeared. The plate is washed for a minute or so, immersed for a few minutes in a 5 per cent. solution

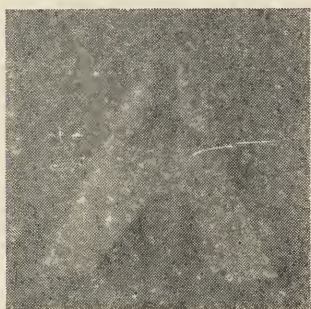
of sodium sulphite, and then returned to the developer. The second development gives, of course, a positive, which is then fixed and washed as usual. Theoretically, no fixing is needed, but, in practice, it is best to put the plate through the regular "hypo" solution. The second development will usually be rather slow. It must also be borne in mind that plates well wetted by developer are much less sensitive to light than plates in the dry condition, hence, if the first development has given a dense picture, a good length of magnesium ribbon should be burned within a few inches of the plate. Care must be taken not to look at the flame, and to hold the ribbon with a pair of tongs. All operations are conducted in the dark room. The process will be found useful for making slides in an emergency.

Among the striking discoveries in relation to light, or, it will be more precise to say, radiant energy, is the existence of rays and material emanations which are invisible to the unassisted human eye, but affect ordinary photographic films and many other substances, and, in some cases, pass freely through objects opaque to ordinary light.

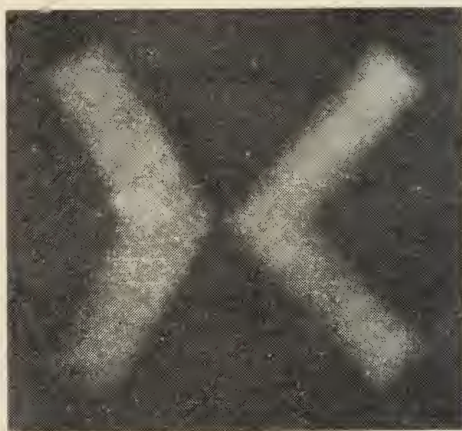
Upon such phenomena as the X-rays, emanations from radioactive substances, ultra-violet and infra-red light I need not dwell here, as ample discussion of these is to be found in recent literature. I want, however, to call attention to a less exploited field, although, even in this, the basic procedures are not very recent. I refer to what has been called "picture-making in the dark," inasmuch as the etymology of the word "photography" prevents us from applying it to any processes but those in which light takes part. I need not stop to give any elaborate history of the investigations. An early contribution was that by W. J. Russell before the Royal Society (*Science*, 1900, 11, 487), who tried many substances and obtained curious results from some of them. M. I. Wilbert (*JOURNAL FRANKLIN INSTITUTE*, 1900, cl, 388) repeated some of Russell's experiments with success. In reviewing these papers, however, it seemed to me that in many cases the impression on the photographic plate might be due to pressure, or mere physical contact, rather than an emanation tangible or intangible. I wish to say, frankly, that I have failed to obtain many of the results reported by Russell and Wilbert, even though following their methods as closely as the descriptions available enable. In the later series of experiments I adopted the plan of interposing

thin paper, usually the ordinary lantern mat, between the object and the sensitive plate, thus preventing actual contact. This method materially retards the action.

It has seemed to me that the procedures that I intend to summarize briefly may be called skotography (from Greek *skotos*, darkness). One of the most active skotographic surfaces is obtained by scratching or polishing common zinc battery plates. Thin zinc sheets do not seem to be so active, nor does sand-papering the zinc plates yield very good results. If one scratches on a tarnished and corroded zinc plate a design, by means of a sharp steel tool, and then lays a dry plate (I used ordinary lantern plates) upon this, with a thin paper between with some perfora-



Negative produced by aluminum.



Negative produced by Eastman "Flash-sheet."

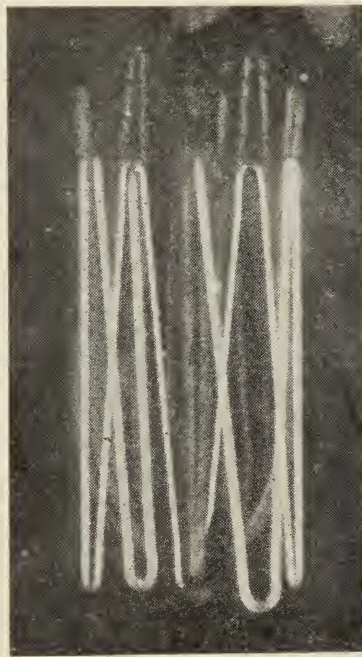
tion or a cut-out design, and allows this combination to remain in the dark for a couple of days, a distinct impression will be made on the sensitive plate that can be brought out by ordinary development. Often the metal is active enough to produce a marked effect in a few hours. Russell expressed the opinion that emanations of minute amounts of hydrogen dioxide produce the effects, and that the dioxide is in some way formed by the fresh surface of metal, but I have not yet obtained any information to enable me to form an opinion as to the cause. Magnesium and zinc seem to be specially active; thin sheet iron did not produce any effect. Aluminum has moderate activity. I obtained a strong effect with the so-called "Flash-sheets" manufactured by the Eastman Kodak Company. Bibulous paper impregnated with old oil of turpentine gave no appreciable effect, but impregnated with

commercial solution of hydrogen dioxide and allowed to get nearly dry before testing gave a feeble picture.

Some experiments have been made on the photographic and other properties of commercial luminous paint. This seems to be composed largely of calcium sulphide in a fixed oil. I have used it spread on glass plates and have found the most convenient way to get an even coating is to dilute the material with gasoline and pour the mixture, as was the custom with the collodion used in the old wet-plate process. When dry the paint forms a some-



Tungsten filament. Ordinary plate. Positive (reversal).



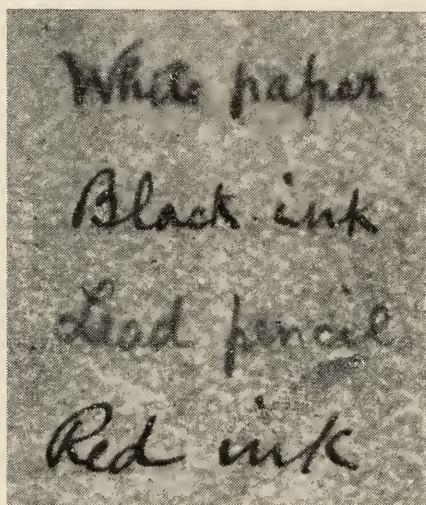
Tungsten filament. "Hydra" plate. Positive (no reversal).

what granular, slightly cream-colored film, which will emit for some time a soft, bluish light after a few seconds' exposure to any ordinary source of light; but the most satisfactory results are obtained from sunlight and arc light. Incandescent electric lights, even powerful tungsten lamps, are somewhat slow in action.

Many interesting experiments may be performed with the coated plates. If a piece of ordinary blue and ordinary red glass are placed upon a luminous-paint surface and then exposed to the direct light of an arc lamp for about half a minute, it will be found that under the blue glass a strong luminosity is developed, but under the red glass almost no effect is produced. A still more

curious effect is that if the entire surface of a coated plate is made luminous and then a portion covered with red glass and again exposed to the light, that part under the red will rapidly lose luminosity. The effect may be also shown by covering a portion of the luminous surface with opaque paper, and holding the plate near the red light of the dark room. A rapid falling off in luminosity will occur over the surface illuminated by the red rays. I do not mean that the luminosity merely appears less in the red light, but it is actually diminished.

Luminous paint may find a practical value in some copying work. Ordinary paper is moderately transparent to it, but writing



Relative opacity of common writing materials to rays from luminous paint.

and printing inks are rather opaque. If, therefore, we render a plate luminous, place it beneath a written or printed page, and lay a sensitive plate upon the page (these operations being, of course, carried out in the dark), it will be found that an exposure of ten or fifteen minutes will suffice to make a latent image on the sensitive plate which can be developed in the usual way. Experiments with gelatins colored with artificial colors have shown that the rays from luminous paint pass freely through violet and blue films, but scarcely at all through green and red films, and therefore no great difference is noted in the negative obtained when such screens are used with ordinary and with panchromatic plates. The panchromatic plates furnished by the Paget Company, which cannot be developed in red light, and the common lantern slide plates,

which may be used freely in red light, gave nearly the same negatives. A Lumière color-plate was also tried; it was found that no appreciable effect was obtained through the green and red films.

So far as I have experimented, the emanation from luminous paints goes equally through glass, quartz, thin films of celluloid, gelatin, barite, calcite, and kyanite, but this phase of the problem is still under investigation. A photographic novelty of practical value is the Paget "Hydra" plate. The emulsion of this contains some hydrazin sulphate, a synthetic product which materially controls over-exposure. I have made tests of the plates by exposing them to the light of a 60-watt tungsten within a few inches of the camera for ten minutes. This is sufficient to produce complete reversal, by over-exposure, in an ordinary plate, but reversal did not occur with "Hydra" plate. Several important uses of such a plate will occur to practical photographers.

Precipitation of Gold and Silver from Cyanide Solutions.

H. A. MEGRAW. (*Eng. and Min. J.*, xcvi, 1232.)—The solution to be precipitated should be quite clear. Four precipitants are used: the electric current, charcoal, aluminum, and zinc. *Electrolysis* was employed in South Africa for several years. Iron anodes and lead cathodes were used, the deposited metal being stripped off the latter from time to time. By using relatively high current density the metal is precipitated as a sludge or slime which can be wiped from the cathode. Electrolysis regenerates an appreciable amount of cyanide, but the precipitate is hard to melt and contains all the metals taken up by the cyanide liquor. The use of *charcoal* is restricted. That made from soft wood is most efficient; 100 pounds of charcoal, twice re-burned, will carry 30 to 40 ounces of metal, and the ash is easily melted into bullion. The action of charcoal is probably due to occluded gases. *Aluminum* has been introduced recently in several mills. It does not combine with the cyanide as zinc does, and thus re-generates a certain quantity of the salt. *Zinc* is the most generally used precipitant, either as shavings or, better, as dust. A slight excess of cyanide must be present to prevent the precipitation of zinc hydroxide. In cyaniding old amalgamation tailings mercury is dissolved to a large extent and almost entirely precipitated by zinc; it may be recovered by retorting the precipitate. Zinc shavings are usually screened in recovering the values, so as to remove the coarse metal which is returned to the precipitation boxes. The fine portion, 60- to 80-mesh, is generally treated with acid, the residue constituting high-grade material, which is added to the undersize from the finer screens. Zinc dust precipitate only requires filter-pressing before melting down.

Magnesia and Dolomite Portland Cements and Their Properties. M. V. GLASENAPP. (*Chem. Zeit.*, xxxviii, 589.)—The calcium oxide in Portland cement was replaced by an equivalent quantity of magnesium oxide; the clinker then contained 59 per cent. MgO and 41 per cent. silicate. To effect solution of the magnesia in the silicate a much higher temperature (1700° to 1800° C.) was required than in the case of ordinary Portland cement. The magnesia cement only reacted with water after six to eight months, crystals, apparently of magnesium hydroxide, then being discernible. No gel formation could be detected in this period. The dolomite cement prepared from normal dolomite required a temperature of 1600° C. It was but little affected by water and the magnesia prevented the separation of calcium hydrosilicate crystals. The use of magnesia as a substitute for calcium oxide is thus impracticable, although there is a possibility that ignited magnesite might be added to Portland cement without injurious effect; since, although the magnesia combined with silica is hydraulically inactive, caustic magnesia in the form of a very fine powder slowly hardens into monoliths of great stability. The higher the temperature of burning the more slowly does the magnesia harden.

The Hardness of Iron—Carbon Alloys. R. VONDRÁČEK. (*Int. Zeits. Metall.*, vi, 172.)—Andrew's theory that the hardness of quenched steels is due to the presence of finely divided cementite embedded in a ground mass of austenite and α -iron is not in accord with the law that the hardness of such alloys is the mean of the corresponding hardness values of the components, nor with the results of the author's experiments on the electrical conductivity of hardened steels. The total carbon in quenched steels is practically all in solution, and the theory is advanced that the hardness is a particular function of the transformation, and is due to the breaking up of the metal, as it were, during re-crystallization. In this respect there is no essential difference between iron alloys and bronzes. It is deduced, from the resistance of hypoeutectoid steels, that the ferrite which they contain has an appreciable carbon content, which increases as the total carbon increases. Eutectoid ferrite probably contains from 0.06 to 0.07 per cent. carbon, and with falling temperature the carbon content rises to a maximum of 0.14 per cent.

Absorption of Nitrogen by Calcium. R. BRANDT. (*Z. Angew. Chem.*, xxvii, 424.)—Calcium, in pieces weighing 3 to 5 grammes, is completely converted into Ca_3N_2 on heating to 400° to 500° C. in nitrogen. The pieces retain their form. The speed of the reaction increases from 300° to 440° C., then decreases, and is zero at about 800° C., the melting-point of calcium. Above this temperature the speed again rises to a considerable value.

THE THUNDERSTORM AND ITS PHENOMENA.*

BY

W. J. HUMPHREYS, C.E., Ph.D.,

Professor of Meteorological Physics, U. S. Weather Bureau, and George Washington University.

The downrush of air clearly produces a vertically directed pressure on the surface of the earth, in the same manner that a horizontal flow produces a horizontally directed pressure against the side of a house. But a pressure equal to that given by 2 mm. of mercury, a pressure increase frequently reached in a thunderstorm, would mean about 2.72 grammes per square centimetre, or 27.2 kilogrammes per square metre, and require a wind velocity of roughly 50 kilometres per hour or 14 metres per second. Now, the velocity of the downrush of air in a thunderstorm is not at all accurately known, but while at times probably very considerable, the above value of 14 metres per second seems to be excessive; in fact, its average value may not be even half so great. If in reality it is not, then, since the pressure of a wind varies as the square of its velocity, it follows that less than one-fourth of the actual pressure increase can be caused in this way. Hence it would seem that there probably is at least one other pressure factor, and, indeed, such a factor obviously exists in the check to the horizontal flow caused by vertical convection.

To make this point clear: Assume two layers of air, an upper and a lower, flowing parallel to each other. Let their respective masses per unit length in the direction of their horizontal movement be M and m , and their velocities V and v . Now, if, through convection, say, the whole or any portion of the lower layer is carried aloft, obviously it must be replaced below by an equal amount of the upper layer.

Let the whole of the lower layer be carried up. This layer, to produce the rain that was above assumed, 2 centimetres, will have to be at least 1 kilometre deep, and if it should merely change places with the upper air, or if the different layers should mingle and assume a common velocity, V' , there obviously would be no

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change in the total linear momentum, nor in the flow. In symbols we would have the equation

$$MV + mv = (M + m) V'.$$

Mere mingling, therefore, of the two air currents, upper and lower, cannot change the depth of the atmosphere, nor, therefore, the height of the barometer. But then in the case of atmospheric convection we have something more than the simple mingling of two air currents, and the linear momentum does not, in general, remain constant. The increased surface velocity following convection, a phenomenon very marked in the case of a thunderstorm, causes an increased frictional drag and therefore a greater or less decrease in the total flow. Suppose this amounts to the equivalent of reducing the velocity of a layer of air only 25 metres thick from V to v , and let $V = 5v$. That is, the one three hundred and twentieth part of the atmosphere has its flow reduced to one-fifth its former value. This would reduce the total flow by about 1 part in 400, and thereby increase the barometric reading by nearly 2 millimetres.

It would seem, then, that the friction of the thunderstorm gust on the surface of the earth, through the consequent decrease in the total linear momentum of the atmosphere and, therefore, its total flow, must be an important contributing cause of the rapid and marked increase of the barometric pressure that accompanies the onset of a heavy thunderstorm.

To sum up: The chief factors contributing to the increase of the barometric pressure during a thunderstorm appear to be, possibly in the order of their magnitude: (a) Decrease of horizontal flow, due to surface friction. (b) Vertical wind pressure, due to descending air. (c) Lower temperature. (d) Decrease in absolute humidity.

Thunderstorm Temperatures.—Before the onset of the storm the temperature commonly is high, but it begins rapidly to fall with the first outward gust and soon drops often as much as 5° C. to 10° C. because, as already explained, this gust is a portion of the descending air cooled by the cold rain and by its evaporation. As the storm passes the temperature generally recovers somewhat, though it seldom regains its original value.

Thunderstorm Humidity.—As previously explained, heavy rain, at least up in the clouds, and therefore much humidity, and

a temperature contrast sufficient to produce rapid vertical convection, are essential to the genesis of a thunderstorm. Hence during the early forenoon of a thunderstorm day both the absolute and the relative humidity are likely to be high. Just before the storm, however, when the temperature has greatly increased, though the absolute humidity still is high, the relative humidity is likely to be rather low. On the other hand, during and immediately after the storm, because chiefly of the decrease in temperature, the absolute humidity is comparatively low and the relative humidity high.

“Rain-gush.”—It has frequently been noted that the rainfall is greatest after heavy claps of thunder, a fact that appears to have given much comfort and great encouragement to those who maintain the efficacy of mere noise to induce precipitation—to jostle cloud particles together into raindrops. The correct explanation, however, of this phenomenon seems obvious: The violent turmoil and spasmodic movements within a large cumulus or thunderstorm cloud cause similar irregularities in the condensation and resulting number of raindrops at any given level. These in turn, as broken by the air currents, give local excess of electrification and of electric discharge or lightning flash. We have, then, starting toward the earth at the same time and from practically the same level, mass, sound, and light. The light travels with the greatest velocity, about 300,000 kilometres per second, and therefore the lightning flash is seen before the thunder is heard; its velocity being, roughly, only 330 metres per second. But the rain falls much slower still and therefore reaches the ground after the thunder is heard. In reality it is the excessive condensation or rain formation up in the cumulus cloud that causes the vivid lightning and the heavy thunder. According only to the order in which their several velocities cause them to reach the surface of the earth it might appear, and has often been so interpreted, that the lightning, first perceived, was the cause of the thunder, which, indeed, it is, and that the heavy thunder, next in order, was the cause of the excessive rain, which most certainly it is not.

Thunderstorm Velocity.—The velocity of the thunderstorm is simply the velocity of the atmosphere in which the bulk of the cumulus cloud happens to be located. Hence as the wind at this level is faster by night than by day and faster over the ocean

than over land, it follows that exactly the same relations hold for the thunderstorm, that it travels faster over water than over land and faster by night than by day. The actual velocity of the thunderstorm, of course, varies greatly, but its average velocity in Europe is 30 to 50 kilometres per hour; in the United States, 50 to 65 kilometres per hour.

Hail.—Hail, consisting of lumps of roughly concentric layers of compact snow and solid ice, is a conspicuous and well-known phenomenon that occurs during the early portion of most severe thunderstorms. But in what portion of the cloud it is formed and by what process the layers of ice and snow are built up are facts that, far from being obvious, become clear only when the mechanism of the storm itself is understood.

As before, let the surface temperature be 30° C. and the absolute humidity 40 per cent., or the dew point 15° C. Under these conditions saturation will obtain, and, therefore, cloud formation will begin when the surface air has risen to an elevation of 1.5 kilometres. Immediately above this level the latent heat of condensation reduces the rate of temperature decrease with elevation to about half its former value, nor does this rate rapidly increase with further gain of height. Hence, usually, for the above assumptions correspond in general to average thunderstorm conditions, it is only beyond the 4-kilometre level that freezing temperatures are reached. It is therefore only in the upper portions of cumulus clouds, the portions that clearly must consist of snow particles and undercooled fog or cloud droplets, that hail can either originate or greatly grow.

But what, then, is the process by which the nucleus of the hailstone is formed and its layer upon layer of snow and ice built up? Obviously such drops of rain as the strong updraft within the cloud may blow into the region of freezing temperatures will quickly congeal and also gather coatings of snow and frost. After a time each incipient hailstone will get into a weaker updraft, for this is always irregular and puffy, or else will tumble to the edge of the ascending column. In either case it will then fall back into the region of liquid drops, where it will gather a coating of water, a portion of which will at once be frozen by the low temperature of the kernel. But again it meets an upward gust, or falls back where the ascending draft is stronger, and again the cyclic journey from realm of rain to region of snow is begun;

and each time—there may be several—the journey is completed a new layer of ice and a fresh layer of snow are added. In general the size of the hailstones will be roughly proportioned to the strength of the convection current, but since their weights vary approximately (they are not homogeneous) as the cube of their diameters while the supporting force of the upward air current varies, also approximately, as only the square of their diameters it follows that a limiting size is quickly reached. It is also evident, from the fact that a strong convection current is essential to the formation of hail, that it can occur only where this convection exists, that is, in the front portion of a heavy to violent thunderstorm.

Some meteorologists hold that the roll scud between the ascending warm and descending cold air is the seat of hail formation, but this is a mistaken assumption. Centrifugal force would throw a solid object, like a hailstone, out of this roll probably before a single turn had been completed. Besides, and this objection is, perhaps, more obviously fatal than the one just given, the temperature of the roll scud, because of its position, the lowest of the whole storm cloud, clearly must be many degrees above the freezing point. Indeed, as the above calculation shows, temperatures low enough for the formation of hail cannot often obtain at levels much less than three times that of the scud, and therefore it clearly is in the higher levels of the cumulus and not in the low scud that hail must have its genesis and make its growth.

Lightning.—About the middle of the eighteenth century Franklin and others clearly demonstrated that the lightning of a thunderstorm and the discharge of an ordinary electric machine are identical in nature, and thereby established the fact that many of the properties of the former may logically be inferred from laboratory experiments with the latter. There is, however, one important source of difference between the two phenomena that does not seem always to be clearly kept in mind, namely, the distribution of the charge. In the one case, that of the laboratory experiment, the charge commonly exists almost wholly on the surface of the apparatus used, while in the other, that of the thunderstorm, it is irregularly distributed throughout the great cloud volume. Hence the two discharges, lightning and laboratory sparks, necessarily differ from each other in important details.

Nevertheless in each case the atmosphere must be ionized before the discharge can take place freely, and this condition seems, at times at least, to establish itself progresso-spasmodically. That is, a small initial discharge, losing itself in a terminal brush, is rapidly followed by another and another, each losing itself in a manner similar to the first, until a path from pole to pole is sufficiently ionized to permit of a free flow and quick exhaustion of the remaining charge. Fig. 23, copied from a photograph obtained by Walter,⁹ on a rapidly moving plate, shows how a laboratory spark spasmodically (doubtless at the period of electrical oscillation) ionizes the air from either pole and thus progressively extends and finally closes the conducting path of complete discharge. There appears also to be good evidence that the

FIG. 23.



The growth of an electric spark discharge (Walter).

lightning discharge often builds itself up in a manner generally similar, though, perhaps, radically different, in certain details. As already implied, ordinary laboratory apparatus has a free period of electrical oscillation, and therefore an electrical discharge from such apparatus is oscillatory in nature, but as yet there seems to be no certain evidence that lightning discharges ever are distinctly oscillatory. They frequently are pulsatory, discharge after discharge taking place in the same direction and along the same path, as we shall see later; but this is an entirely different thing from being oscillatory, or consisting of a decreasing series the units of which are alternately in opposite directions.

It will be convenient, in further discussing the facts known about lightning, to classify it according to its general appearance.

Streak Lightning.—When the storm is close by, the lightning discharge almost invariably appears to the unaided eye as one or more sinuous lines or streaks of vivid white or pink. Sinuous,

because electrically the atmosphere is heterogeneous or unequally ionized. There often appears to be a main trunk with a number of branches, all occurring at the same time and instantaneously. At other times there seem to be two or more simultaneous but locally disconnected streaks. Frequently the discharge continues flickeringly (on rare occasions even steady, like a white-hot wire) during a perceptible time—occasionally a full second.

But all these phenomena are best studied by means of the camera, and have been so studied by several persons, among whom Walter, of Hamburg, and Larsen, of Chicago, are two of the

FIG. 24.



Streak lightning, stationary camera; companion to Fig. 25 (Walter).

most persistent and successful. Stationary cameras, revolving cameras, stereoscopic cameras, cameras with revolving plates; and cameras with spectrographic attachments have all been used, separately and jointly, and the results have abundantly justified the time and the labor devoted to the work.

Fig. 24, copied by permission from one of Walter's unpublished negatives, shows the ordinary tracery of a lightning discharge when photographed with a stationary camera. It is only a permanent record of the appearance of the lightning to the unaided eye. Fig. 25, however, also copied by Walter's kind permission from one of his unpublished photographs, is a record of the same discharge obtained with a rotating camera. It will be noted that the more nearly vertical discharge occurred but once,

or was single; that this discharge was quickly followed by a second along the same path to about one-fourth of the way to the earth where it branched off on a new course; that the second discharge was followed in turn at short but irregular intervals by a whole series of sequent discharges; that most of the discharges appeared as narrow, intensely luminous streaks, and that one of the sequent discharges appeared, not to the eye, but on the plate of the rotating camera, as a broad band or ribbon. On close inspection it will be obvious that the plaid-like ribbon effect is due, the warp to irregularities in the more or less continuous discharge, and the

FIG. 25.



Streak lightning (sequent discharges), rotating camera; companion to Fig. 24 (Walter).

woof to roughly end-on and therefore brighter portions of the streak. Another point particularly worthy of attention is the fact that while the first discharge has several side branches the following ones remain entire from end to end and are nowhere subdivided.

Fig. 26, taken from a photograph obtained by Mr. Larsen, of Chicago, and kindly loaned for use here by the Smithsonian Institution, shows another series of sequent discharges similar to those of Fig. 25, except that in this case there was no ribbon discharge. The time of the whole discharge, as calculated by Mr. Larsen, was 0.315 second. Here, too, side branches occur with the first, but only the first, discharge. This, however, is not

an invariable rule for occasionally, as illustrated by Fig. 27, copied from a published photograph by Walter, the side branches persist through two or three of the first successive discharges, but not through all. In such case each tributary when repeated follows, as does the main stream, its own original channel.

The phenomenon of sequent discharges, all along the same path, and the disappearance of the side branches with or quickly after the first discharge both seem reasonably clear. The first

FIG. 26.



Streak lightning (sequent discharges), rotating camera (Larsen).

discharge, however produced, obviously takes place against very great resistance, and therefore under conditions the most favorable for the occurrence of side branches or ramifications. But the discharge itself leaves the air along its path temporarily highly ionized—puts a temporary line conductor, with here and there a poorer conducting branch, in the atmosphere. This conductor is not only temporary (half the ions are reunited in about 0.15 second, the air being dusty) but also so extremely fragile as to be liable to rupture by the atmospheric violence it itself creates. Because partly, perhaps, of just such interruptions, and because

also of the volume distribution of the electricity which prevents a sudden and complete discharge, the actual discharge is divided into a number of partials that occur sequentially. Obviously the breaks in the conducting (ionized) path, if they exist, are only here and there and but little more than sufficient to interrupt the flow. Hence the next discharge, if it occurs quickly, must follow

FIG. 27.



Streak lightning (sequent discharges), rotating camera (Walter).

the conducting and, therefore, original discharge path. Besides, in the subsequent discharges the original side branches will be quickly abandoned because of their greater resistance, or, what comes to the same thing, because of the more abundant ionization and consequent higher conductivity of the path of heaviest discharge.

This leaves the genesis of the initial discharge, often if not usually the only one, to be explained, and indeed this probably

is, at present, the least understood of all the many thunderstorm phenomena. Judging from the voltages required to produce laboratory sparks, roughly 30,000 volts per centimetre, it is not obvious how such tremendous voltage differences can be established between clouds or between a cloud and the earth as would seem to be necessary to produce a discharge kilometres in length, as often occurs. Of course the potential of individual drops may grow in either of two ways: (*a*) By coalescence of equally charged smaller drops into larger ones. In this case, since capacity is directly proportioned to the radius, the potentials of the individual drops must be proportional to the squares of their radii. (*b*) By evaporation of equally charged drops. Here the potentials of the individual drops obviously are inversely proportional to their radii. In each case the tendency of the separate drops to discharge is increased, but the potential of the cloud as a whole remains unchanged. At present, therefore, one can do but little more than speculate on the subject of the primary lightning discharge, but even that much may be worth while since it helps one to remember the facts.

As already explained the electrical separation within a thunderstorm cloud is such as to place a heavily charged positive layer (lower portion of the cloud) between the earth and a much higher, also heavily charged, negative layer (upper portion of the cloud). Hence the discharges, or lightning, from the intermediate or positively charged layer may be either to the negative portion above, in some cases even to an entirely different cloud, or to the earth below. Further, through the sustaining influence and turbulence of the uprushing air, there must be formed at times and places practically continuous sheets and streams of water, of course heavily charged and at high potential, and also layers and streaks of highly ionized air; that is, electrically speaking, heavily charged conducting sheets and rods, whether of coalesced drops or of ionized air, are over and over, so long as the storm lasts, momentarily placed here and there within the positively charged mass of the storm cloud.

Let us see, then, what might be expected as the result of this peculiar disposition of charges and conductors, the result, namely, of the existence of a heavily surface-charged vertical conductor in a strongly volume-charged horizontal layer or region, above and

below which there are steep potential gradients to negatively charged parallel surfaces.

The conductor will be at the same potential throughout, and therefore the maxima of potential gradients normal to it will be at its ends, where, if these gradients are steep enough, and the longer the conductor the steeper the gradients, brush discharges will take place. Assume, then, that a brush discharge does take place and that there is a supply of electricity flowing into the conductor to make good the loss. The brush and the line of its most vigorous ionization necessarily will be directed along the potential gradient or toward the surface of opposite charge. But this very ionization automatically increases the length of the conductor, for a path of highly ionized air is a conductor, and as the length of the conductor grows so, too, does the steepness of the potential gradient at its forward or terminal end, and as the steepness of this gradient increases the more vigorous the discharge, always assuming an abundant electrical supply. Hence, an electric spark once started within a thunderstorm cloud has a good chance, by making its own conductor as it goes, of geometrically growing into a lightning flash of large dimensions. Of course when the electrical supply is small the lightning is feeble and soon dissipated.

Whether the discharge actually does burrow its way through the atmosphere in some such manner as that indicated probably would be difficult, though not necessarily impossible, of observation. Indeed, a roughly analogous phenomenon¹⁰ can be produced on a photographic plate by bringing in contact with the film, some distance apart, two conducting points attached to the opposite poles of an influence machine. Brush discharges develop about each point, but the glow at the negative pole detaches itself and slowly meanders across the plate toward the positive point. As it goes it continually builds for itself, out of the silver of the emulsion, a conducting path.

Rocket Lightning.—Many persons have observed what at least seemed to be a progressive growth in the length of a streak of lightning. In some cases¹¹ this growth or progression has appeared so slow as actually to suggest the flight of a rocket, hence the name.

At first one might well feel disposed to regard the phenomenon in question as illusory, but it has been too definitely described and too frequently observed to justify such summary dismissal.

Naturally, in the course of thousands of lightning discharges, many degrees of ionization, availability of electrical charge, and slopes of potential gradient are encountered. Ordinarily the growth of the discharge, doubtless, is in a geometric ratio and the progress of its end exceedingly swift, but it seems possible for the conditions to be such that the discharge can barely more than sustain itself, in which case the movement of the flash terminal may, possibly, be relatively slow.

Ball Lightning.—Curious luminous balls or masses, of which C. de Jans ¹² probably has given the fullest account, have time and again been reported among the phenomena observed during a thunderstorm. Most of them appear to last only a second or two and to have been seen at close range, some even passing through a house, but they have also appeared to fall, as would a stone,¹³ or like a meteor, from the storm cloud, and along the approximate path of both previous and subsequent lightning flashes. Others appear to start from a cloud and then quickly return, and so on through an endless variety of places and conditions.

Doubtless many reported cases of ball lightning are entirely spurious, being either fixed or wandering brush discharges or else nothing other than optical illusions, due in most cases probably to persistence of vision. But here, too, as in the case of rocket lightning, the amount and excellence of observational evidence forbid the assumption that all such phenomena are merely subjective. Possibly in some instances, especially those in which it is seen to fall from the clouds, ball lightning may be only extreme cases of rocket lightning, cases in which the discharge for a time just sustains itself. A closely similar idea has been developed in detail by Toepler.¹⁴ It may either disappear wholly and noiselessly, as often reported, or it could perhaps suddenly gain in strength and instantly disappear, as sometimes observed, with a sharp abrupt clap of thunder.

To say that all genuine cases of ball lightning, those that are not mere optical illusions, are stalled thunderbolts, certainly may sound very strange. But that indeed is just what they are according to the above speculation, a speculation that recognizes no difference in kind between streak, rocket, and ball lightning, only differences in the amounts of ionization, quantities of available electricity and steepness of potential gradients.

Sheet Lightning.—When a distant thundercloud is observed

at night one is quite certain to see in it beautiful illuminations, looking like great sheets of flame, that often flicker and glow in exactly the same manner as does streak lightning for well-nigh a whole second. In the daytime and in full sunlight the phenomenon when seen at all appears like a sudden sheen that travels and spreads here and there over the surface of the cloud. Certainly in most cases, so far as definitely known in all cases, this is only reflection from the body of the cloud of streak lightning in other and invisible portions. Conceivably a brush or coronal discharge may take place from the upper surface of a thunderstorm cloud, but one would expect this to be either a faint continuous glow or else a momentary flash coincident with a discharge from the lower portion of the cloud to earth or to some other cloud. But, as already stated, only reflection is definitely known to be the cause of sheet lightning. Coronal effects seem occasionally possible, but that they are ever the cause of the phenomenon in question has never clearly been established and appears very doubtful. It has often been asserted, too, that there is a radical difference between the spectra of streak and sheet lightning, but even this does not appear ever to have been photographically proved.

Beaded Lightning.—Discontinuous or beaded streaks of lightning have been reported from time to time. Indeed the author himself has several times seen, or had the impression of seeing, this phenomenon, but with one or two doubtful exceptions he felt practically certain that it was only an optical illusion. In addition to visual observations of the kind just described many photographs showing streaks of light broken into more or less evenly spaced dashes have been obtained and reported as photographs of beaded lightning. Without exception, however, these seem certainly to be nothing other than the photographs of alternating current electric lights, taken with the camera in motion. The objective reality, therefore, of beaded lightning does not seem at all well established, at least not sufficiently well to justify any serious effort to explain it.

Return Lightning.—This is commonly referred to as the return shock, and is only those relatively small electrical discharges that take place here and there from objects on the surface of the earth coincidently with lightning flashes, and as a result of the suddenly changed electrical strain. These dis-

charges are always small in comparison with the main lightning flash, but at times are sufficient to induce explosions, to start fires, and even to take life.

Dark Lightning.—When a photographic plate is exposed to a succession of lightning flashes, it occasionally happens that one or more of the streak images, on development, exhibits the “Clayden effect”—that is, appears completely reversed—while the others show no such tendency. Obviously, then, on prints from such a negative the reversed streaks must appear as dark lines, and for that reason the lightning flashes that produced them have been called “dark lightning.” There is, of course, no such thing as dark lightning, but the photographic phenomenon that gave rise to the name is real, interesting, and reproducible at will in the laboratory.¹⁵

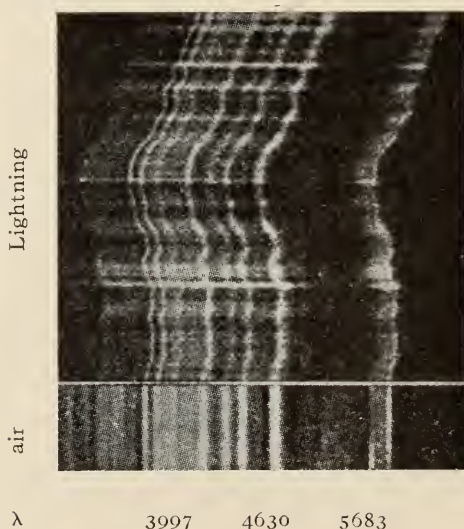
Temperature.—What the temperature along the path of a lightning discharge is no one knows, but it obviously is high, since it frequently sets fire to buildings, trees, and many other objects struck. In an ordinary electrical conductor the amount of heat generated in a given time by an electric current is proportional to the product C^2RT , in which C is the strength of the current, R the ohmic resistance, and T the time in question during which C and R are supposed to remain constant. In a spark discharge of the nature of lightning some of the energy produces effects, such as decomposition and ionization, other than mere local heating, but as experiment shows, a great deal of heat is generated, according, so far as we know, to the same laws that obtain for ordinary conductors. Hence extra heavy discharges, like extra large currents, produce excessive heating, and therefore are far more liable than are light ones to set on fire any objects that they may hit.

Visibility.—Just how a lightning discharge renders the atmosphere through which it passes luminous is not definitely known. It must and does make the air path very hot, as we have seen, but no one has yet succeeded, by any amount of ordinary heating, in rendering either oxygen or nitrogen luminous. Hence it seems well nigh certain that the light of lightning flashes owes its origin to something other than high temperature, probably to internal atomic disturbances induced by the swiftly moving electrons of the discharge.

Spectrum.—Lightning flashes are of two colors, white and

pink or rose. The rose-colored flashes, when examined in the spectroscope, show several lines due to hydrogen which, of course, is furnished by the decomposition of some of the water along the lightning path. The white flashes, on the other hand, show no hydrogen lines or, at most, but faint ones. As one might suspect, the spectrum of a lightning flash and that of an ordinary electric spark in air are practically identical. This is well shown by Fig. 28, copied from an article on the spectrum of lightning by Fox,¹⁶ in which the upper or wavy portion is due to the lightning and the lower or straight portion to a laboratory spark in air.

FIG. 28.



It is often asserted that the spectrum of streak lightning consists wholly of bright lines and that sheet lightning gives only nitrogen bands; and from this it is argued that the latter is not a mere reflection of the first. This assertion is not supported by Fig. 28, the brightest portions of which, the portions that would the longest be seen as reflection grew steadily feebler, coincide with strong nitrogen bands. In this connection, however, it should be remembered that accurate wave-length measurements, and therefore positive identification of the lines of lightning spectra, is not possible, owing to the small dispersion or separation of the lines on all such negatives so far reported.

Duration.—The duration of the lightning discharge is exceedingly variable, ranging from 0.0002 second for a single flash to, in rare cases, even a full second or more for a multiple flash

consisting of a primary and a series of sequent flashes. On rare occasions a discharge of long duration appears *to the eye* to be steady like a glowing solid. Possibly the best measurements of the shorter intervals were made by De Blois¹⁷ with the aid of a high-frequency oscillograph. He found the durations of 38 single peaks, averaging 0.00065 second, to range from 0.0002 second to 0.0016 second. Flashes that last as long as a few tenths or even a few hundredths of a second are almost certainly multiple, consisting of a succession of apparently individual discharges occurring at unequal intervals. Occasionally a practically continuous discharge of varying intensity, but all the time strong enough to produce luminosity, will last a few hundredths of a second.

It must be remembered that the duration of even a single discharge and the length of time to complete the circuit, or ionize a path, from cloud to earth, say, are entirely different things. The latter seems usually (rocket and ball lightning may furnish exceptions) to be of exceedingly short duration, while the former depends upon the supply of electricity and the ohmic resistance directly and upon the potential difference inversely.

Discharges Direct, not Alternating.—Years ago some one for some reason or other, or for no reason, made the statement that the lightning flash is alternating and of high frequency, like the discharge of a Leyden jar, and forthwith, despite the fact that all evidence is to the contrary, it became a favorite dogma of the text-book, passed on unquestioned from author to author and handed down inviolate from edition to edition. There often are a number of successive discharges in a fraction of a second, as photographs taken with a revolving camera show, but they are not only along the same path but also in the same direction. This is obvious from the fact that when the side branches persist, as in Fig. 26, through two or more partial or sequent discharges, they are always turned in the same direction. It is also proved by the direct evidence of the oscillograph.¹⁸

In the case of each separate discharge also the direction seems constant. It may vary in strength, or pulsate, but, apparently, it does not alternate. There are several reasons for concluding that lightning discharges are direct and not alternating, of which the following cover a wide range and probably are the best:

(a) Lightning operates telegraph instruments. If the discharge were alternating it would not do so.

(b) At times it reverses the polarity of dynamos. This requires a direct and not a high-frequency alternating discharge.

(c) The oscillograph¹⁹ shows each surge or pulsation, as well as the whole flash, to be unidirectional.

(d) The relative values of the ohmic resistance, the self-induction, and the capacity, in the case of a lightning discharge, appear usually, if not always, to be such as to forbid the possibility of oscillations.

It has been shown that whenever the product of the capacity by the square of the resistance is greater than four times the self-induction, or, in symbols, that whenever

$$CR^2 > 4L$$

oscillations are impossible. Undoubtedly all these terms vary greatly in the case of lightning discharges, but R , presumably, is always sufficiently large to maintain the above inequality and therefore absolutely to prevent oscillations.

Possibly a calculation giving roughly the numerical order of the terms involved would be helpful. For this purpose assume a cloud whose undersurface is circular with a radius of 3 kilometres, and whose height above the ground is 1 kilometre, and let there be a discharge from the centre of the cloud base straight to the earth: Find a probable value for the self-induction and capacity, and from these the limiting value of the resistance to prevent oscillations, or the value of R in the equation

$$CR^2 = 4L.$$

To find L we have the fact that the coefficient of self-induction is numerically equal to twice the energy in the magnetic field per unit current in the circuit, and the further fact that per unit volume this energy is numerically equal to $H/8\pi$, in which H is the magnetic force. Let a be the radius of the lightning path and assume the current density in it to be uniform. Let b be the equivalent radius of the cylinder, concentric with the lightning path, along which the return or displacement current flows. In this case the energy W of the magnetic field per centimetre length of the discharge is given by the equation

$$W = \log_e \frac{b}{a} + \frac{1}{2}.$$

Let $b = 2$ kilometres and $a = 5$ centimetres. Then $W = \log_e 4 \times 10^4 + \frac{1}{2} = 11$, approximately. Hence the energy of the magnetic field per unit current for the whole length, 1 kilometre, of the flash is represented by the equation

$$W I 10^5 = 11 \times 10^5,$$

hence the self-induction $= 22 \times 10^5 = 22 \times 10^{-4}$ henry.

To find C we shall assume a uniform field between the cloud and the earth. As a matter of fact, this field is not uniform, and the calculated value of C , based upon the above assumption, is somewhat less than its actual value. Assuming, then, a uniform field we have

$$C = \frac{a}{4\pi d} = \frac{\pi 9 \times 10^{10}}{4\pi \times 10^5} = 225 \times 10^3 = 25 \times 10^{-8} \text{ farad, about.}$$

Hence, substituting in the equation

$$CR^2 = 4L,$$

we get

$$R = 190 \text{ ohms per kilometre, approximately.}$$

Neither a , the radius of the lightning path, nor b , the equivalent radius of the return current, is accurately known, but from the obviously large amount of suddenly expanded air necessary to produce the atmospheric disturbances incident to thunder it would seem that 1 centimetre would be the minimum value for a . Also, from the size of thunder clouds, it appears that 10 kilometres would be the maximum value for b .

On substituting these extreme values in the above equations, we get

$$R = 200 \text{ ohms per kilometre, roughly.}$$

From the fact that C varies inversely and L directly as the altitude of the cloud it follows that, other things remaining equal, the height of the cloud has no effect on the value of R per unit length.

If the altitude is kept constant and the size of the cloud varied C will increase directly as the area, and L will increase directly as the natural logarithm of the equivalent radius of the cylinder of return current. Assuming the area of the cloud base to be 1 square kilometre, which certainly is far less than the ordinary size, and computing as above we find

$$R = 850 \text{ ohms per kilometre, roughly.}$$

Again, assuming the base area to be 1000 square kilometres, an area far in excess of that of the base of an ordinary thunder-storm cloud, we find

$$R = 35 \text{ ohms per kilometre, roughly.}$$

It would seem, therefore, that a resistance along the lightning path of the order of 200 ohms per kilometre, or 0.002 ohm per centimetre, would suffice, in most cases, absolutely to prevent electrical oscillations between cloud and earth. In reality the total resistance includes, in addition to that upon which the above calculations are based, the resistance in parallel of the numerous feeders or branches within the cloud itself. In other words, the assumption that the resistance of the condenser plates is negligible may not be strictly true in the case of a cloud. Nor is this the only uncertainty, for no one knows what the resistance along the path of even the main discharge actually is; though, judging from the resistance of an oscillatory electric spark,²⁰ it, presumably, is much greater than the calculated limiting value; and if so, then lightning flashes, as we have seen, must be unidirectional and not alternating.

Length of Streak.—The total length of a streak of lightning varies greatly. Indeed the brush discharge so gradually merges into the spark and the spark into an unmistakable thunderbolt that it is not possible sharply to distinguish between them, nor, therefore, to set a minimum limit to the length of a lightning path. When the discharge is from cloud to earth the length of the path is seldom more than 2 to 3 kilometres, but, in the case of low-lying clouds, may be much less, and especially so when they envelop a mountain peak.

On the other hand, when the discharge is from cloud to cloud the path generally is far more tortuous and its total length much greater, amounting at times to 10, 15, and even 20 kilometres.

Discharge, Where to Where.—As already explained, lightning discharges may be from cloud to earth, from one part to another of the same cloud, or from cloud to cloud. But since the great amount of electrical separation, without which the lightning could not occur, takes place within the rain cloud, it follows that this is also likely to be the seat of the steepest potential gradients. Hence it would appear that lightning must occur most frequently between the lower and the upper portions

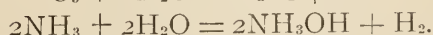
of the same cloud, and this is fully supported by observations. The next in frequency, especially in mountainous regions, is the discharge from cloud (lower portion) to earth, and the least frequent of all, ordinarily, those that take place between one and another entirely independent or disconnected clouds.

Explosive Effects.—The excessive and abrupt heating caused by the lightning current explosively and greatly expands the column of air through which it passes. It even explosively vaporizes such volatile objects as it may hit that have not sufficient conductivity to carry it off. Hence, chimneys are shattered, shingles torn off, trees stripped of their bark or utterly slivered and demolished, kite and other wire fused or volatilized, holes melted through steeple bells and other large pieces of metal, and a thousand other seeming freaks and vagaries wrought.

Many of the effects of lightning appear at first difficult to explain, but, except the physiological and, probably, some of the chemical, all depend upon the sudden and intense heating along its path.

Chemical Effects.—As is well known, oxides of nitrogen and even what might be termed the oxide of oxygen, or ozone, are produced along the path of an electric spark in the laboratory. Therefore one might expect an abundant formation, during a thunderstorm, of these same compounds. And this is exactly what does occur, as observation abundantly shows. It seems probable, too, that some ammonia must also be formed in this way, the hydrogen being supplied by the decomposition of rain-drops and water vapor.

In the presence of water or water vapor these several compounds undergo important changes or combinations. The nitrogen peroxide (most stable of the oxides of nitrogen) combines with water to produce both nitric and nitrous acids; the ozone with water gives hydrogen peroxide and sets free oxygen; and the ammonia in the main merely dissolves, but probably also to some extent forms caustic ammonia and hydrogen. Symbolically the reactions seem to be as follows:



The ammonia and also both the acids through the production of soluble salts are valuable fertilizers. Hence, wherever

the thunderstorm is frequent and severe, especially, therefore, within the tropics, the chemical actions of the lightning may materially add, as has recently been shown,²¹ to the fertility of the soil and the growth of crops.

Danger.—It is impossible to say much of value about the danger from lightning. Generally it is safer to be indoors than out during a thunderstorm, especially if the house has a well-grounded metallic roof. If outdoors it is far better to be in a valley than on the ridge of a hill, and it is always dangerous to take shelter under a tree—the taller the tree, other things being equal, the greater the danger. Some varieties of trees appear to be more frequently struck, in proportion to their numbers and exposure, than others, but no tree is immune. It seems that, in general, the trees most likely to be struck are those that have either an extensive root system, like the locust, or deep tap roots, like the pine, and this for the very obvious reason that they are the best grounded and therefore offer, on the whole, the least electrical resistance.

Finally, if one has to be outdoors and exposed to the danger of a violent thunderstorm it is advisable, so far as danger from the lightning is concerned, to get soaking wet, because wet clothes are much better conductors, and dry ones poorer, than the human body. In extreme cases it might even be advisable to lie flat on the wet ground.

As just implied, the contour of the land is an important factor in determining the relative danger from lightning because, obviously, the chance of a cloud-to-earth discharge, the only kind that is dangerous, varies inversely as the distance between them. Hence thunderstorms are more dangerous in mountainous regions, at least in the higher portions, than over a level country. For this same reason also, distance of cloud to earth, there exists on high peaks a level or belt of maximum danger, the level, approximately of the base of the average cumulus cloud. The tops of the highest peaks are seldom struck, simply because the storm generally forms and runs its course at a lower level.

Clearly, too, for any given section the lower the cloud the greater the danger. Hence a high degree of humidity is favorable to a dangerous storm, partly because the clouds will form at a low level and partly because the precipitation will be abundant. Hence, too, a winter thunderstorm, because of its generally lower

clouds, is likely to be more dangerous than an equally heavy summer one.

The Ceraunograph.—Various instruments, based upon the principles of “wireless” receivers, have been devised for recording the occurrence of lightning discharges. Of course the sensitiveness of the instrument, the distance and the magnitude of the discharge all are factors that affect the record, but by keeping the sensitiveness constant, or nearly so, it is possible with an instrument of this kind to estimate the approximate distance, progress, and to some extent even the direction of the storm. Nevertheless there does not appear to be much demand for this information, and therefore at present the ceraunograph is but sparingly used.

Thunder.—For a long while no one had even a remotely satisfactory idea in regard to the cause of thunder, and it is not a rare thing even yet to hear such a childish explanation as that it is the noise caused by the bumping or rubbing of one cloud against another.

As above explained, because of the sudden and intense heating due to the lightning discharge the air column through which it passes is so greatly and so abruptly expanded as to simulate in every detail a violent explosion, and therefore to send out from every portion of its path a steep compression wave, which, of course, is the real physical cause of the thunder. The expansion, obviously, is followed by a cooling and contraction, but though this action is rapid it probably is not nearly rapid enough to have anything to do with the production of thunder, though many have suggested it as the whole cause.

Rumbling.—Probably the most distinctive characteristic of thunder is its long-continued rumbling and great variation in intensity. Several factors contribute to this peculiarity, among them:

Inequalities in the distances from the observer to the various portions of the lightning's path. Hence the sound, which ordinarily travels about 330 metres per second in the air, will not all reach him at the same time, but continuously over an appreciable interval of time.

Crookedness of path. Because of this condition it often happens that sections of the path here and there are, each through its length, at nearly the same distance from the observer or

follow roughly the circumferences of circles of which he is the centre, while other portions are directed more or less radially from him. This would account for, and doubtless in a measure is the correct explanation of, some of the loud booming effects or crashes that accompany thunder.

Succession of discharges. When, as often happens, several discharges follow each other in rapid succession there is every opportunity for all sorts of irregular mutual interference and reinforcement of the compression waves or sound impulses they send out.

Reflection. Under favorable conditions the echo of thunder from clouds, hills, and other reflecting objects certainly is effective in accentuating and prolonging the noise and rumble. But the importance of this factor generally is greatly overestimated, for ordinarily the rumble is substantially the same whether over the ocean, on the prairies, or among the mountains.

Distance Heard.—The distance to which thunder can be heard seldom exceeds 25 kilometres, while ordinarily, perhaps, it is not heard more than half so far. To most persons, familiar with the great distances to which the firing of large cannon is still perceptible, the relatively small distances to which thunder is audible is quite a surprise. It should be remembered, however, that both the origin of the sound and often the air itself as a sound conductor are radically different in the two cases. The firing of cannon or any other surface disturbance is heard farthest when the air is still and when, through inversion or otherwise, it is so stratified as in a measure to conserve the sound energy between horizontal planes. Conversely, sound is heard to the least distance when the atmosphere is irregular in respect to either its temperature or moisture distribution, or both, for these conditions favor the production of internal sound reflections and the dissipation of energy. Now the former or favorable conditions occasionally obtain during the production of ordinary noises, including the firing of cannon, but never obtain during a thunderstorm. In fact, the thunderstorm is especially likely itself to establish the second set of the above conditions, or those least favorable to the far carrying of sound.

Then, too, when a cannon, say, is fired the noise all starts from the same place, the energy is concentrated, while in the case of thunder it is stretched out over the entire length of the

lightning path. In the first case the energy is confined to a single shell; in the second it is diffused through an extensive volume. It is these differences in the concentration and the conservation of the energy that cause the cannon to be heard much farther than the heaviest thunder, even though the latter almost certainly produces much the greater total atmospheric disturbance.

Normal Atmospheric Electricity.—The only reason for mentioning normal atmospheric electricity in connection with thunderstorms is to emphasize the fact that, contrary to what many suppose to be the case, there is but little relation, in the sense of cause and effect, between these two phenomena. Thus while the difference in electrical potential between the surface of the earth and a point at constant elevation is roughly the same at all parts of the world, the number and intensity of thunderstorms vary greatly from place to place. Further, while the potential gradient at any given place is greatest in winter the number of thunderstorms is most frequent in summer, and while the gradient, in the lower layer of the atmosphere, at many places, usually is greatest from 8 to 10 o'clock, both morning and evening, and least at 2 to 3 o'clock P.M. and 3 to 4 o'clock A.M., no closely analogous relations hold for the thunderstorm.

Probably the most interesting conclusion in regard to normal atmospheric electricity so far drawn from observation and experiment is this: That the earth everywhere, land and water and from pole to pole, is a negatively charged sphere of practically constant surface density, surrounded by an atmosphere so conducting that it is constantly carrying away a current that amounts on the whole to about 1000 ampères.

Where the supply of negative electricity comes from that keeps the surface of the earth on the whole negatively charged in spite of this steady great loss, or how the outgoing current is compensated, no one knows. Rain does not help matters, for, as we have seen, that is prevailingly positive, whereas we need, to compensate the loss, to bring back negative electricity and a great deal of it. Neither, so far as known, is compensation supplied by means of the lightning, for, in the great majority of cases, this, too, is positive from cloud to earth. And so the puzzle remains. As Simpson²² puts it: .

“A flow of negative electricity takes place from the surface of the whole globe into the atmosphere above it, and this necessi-

tates a return current of more than 1000 ampères; yet not the slightest indication of any such current has so far been found, and no satisfactory explanation for its absence has been given."

Much more, of course, might be said on this subject, for it is a big one on which many have labored, but perhaps the above is sufficient for the purpose of this final section, namely, to show that, contrary to opinions often held, there is no obvious and close relation between the thunderstorm and normal atmospheric electricity; that, according to our best evidence, they are distinct and independent phenomena.

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[DATED, WEATHER BUREAU, WASHINGTON, D. C., JULY 17, 1914.]

The United States Bureau of Mines has begun the collection of a general library of petroleum literature, under the direction of W. A. Williams, chief petroleum technologist. The details of this work have been assigned to Dr. David T. Day, who has recently been transferred from the United States Geological Survey as petroleum technologist, and who will also assist in a thoroughly organized research into the chemistry of oils, which is being developed by the Bureau of Mines. The importance of such a library is so manifest that it is hoped all technologists will aid in the work by exchanging with the bureau all available books and maps on this subject.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A WHEATSTONE BRIDGE FOR RESISTANCE THERMOMETRY.

By C. W. Waidner, H. C. Dickinson, E. F. Mueller, and D. R. Harper 3rd.

[ABSTRACT.]

THE Wheatstone bridge described in this paper was designed with especial reference to flexibility of use in measurements with resistance thermometers. The bridge is adapted to use with either the Siemens type or Callendar type of resistance thermometer, or with the potential terminal type of thermometer by the use of the Thomson double bridge method. The instrument is also arranged so that it may be completely self-calibrated.

The 0.01, 0.001, and 0.0001 ohm decades are secured by varying, by means of dial switches, the shunts on three coils permanently connected in the measuring arm of the bridge. The sum of the resistances which are permanently connected is 2.5 ohms when the dials are set on zero, so that in order to measure resistances smaller than this a coil of 2.5 ohms is connected in the adjacent arm of the bridge.

The entire electrical circuit of the bridge, coils, contact blocks, switches, and connectors is totally immersed in an oil-bath thermostat, and special manipulating devices for the links and dials, etc., are provided. Details of construction are shown by photographs and briefly explained in the text.

A new form of hermetically sealed coil, suitable for Wheatstone bridges, potentiometers, and similar apparatus, is fully described and record of its performance reviewed. Such construction eliminates the seasonal variations of resistance (with varying atmospheric humidity) found in coils of the usual types.

The accuracy attainable with the bridge is such that resistances of one ohm or more can be measured to an accuracy of one part in 300,000 in terms of the unit in which the calibration is expressed. This corresponds to an accuracy of about 0.001° for measurements with the platinum resistance thermometer. Low resistances, the accuracy of measurement of which is limited by variations in contact resistances, may be measured to about three-millionths

* Communicated by the Bureau.

of an ohm. The small temperature changes of a few degrees, occurring in calorimetric measurements, may be measured to one or two parts in ten thousand.

THE TOTAL EMISSIVITY OF PLATINUM AND THE RELATION BETWEEN TOTAL EMISSIVITY AND RESISTIVITY.

By Paul D. Foote.

[ABSTRACT.]

THE theory of radiation from metals developed by Aschkinass has been extended and the following general equation has been derived for the total emissivity of a metal:

$$E = 0.5736 \sqrt{rT} - 0.1769 rT$$

where E is the total emissivity at the absolute temperature T , and r the volume resistivity of the metal at this temperature. Experimental observations upon platinum obtained by the use of radiation pyrometers confirmed the above theoretical relation. A table of corrections is given for converting temperatures observed with a radiation pyrometer sighted upon platinum to true temperatures. The following table represents the total emissivity of pure platinum as a function of the temperature:

°C.....	0	200	400	600	800	1000	1200	1400	1700
Emissivity .....	.030	.051	.070	.089	.108	.124	.140	.155	.175

THE EMISSIVITY OF METALS AND OXIDES, II: MEASUREMENTS WITH THE MICROPYROMETER.

By G. K. Burgess and R. G. Waltenberg.

THE micropyrometer may be used conveniently for the approximate determination of the monochromatic emissivities of metals, oxides, etc., in microscopic quantities at high temperatures. It is possible to determine to one per cent. the emissivity of a mass of 0.01 mg. having an area of 0.25 mm.² and a thickness of 0.0005 mm. The determination of the temperature coefficient of emissivity is readily made, as well as the detection of variation of emissivity with change of state, as at the melting-point.

Assuming the emissivity for solid platinum is 0.33 for red light of wave-length $\lambda = 0.65\mu$ and 0.38 for $\lambda = 0.55\mu$, the following, among other results, have been obtained:

EMISSIVITIES OF METALS AND OXIDES WITH MICROPYROMETER.

Metals	Cu	Ag	Au	Pd	Pt	Ir	Rh	Ni	Co	Fe	Mn	Ti
$e\lambda = 0.65\mu$ {solid....	.10	.04	.14	.33	.33	.30	.29	.36	.36	.37	.59	.63
liquid... {	.15	.07	.22	.37	.38	...	.30	.37	.37	.37	.59	.65
$e\lambda = 0.55\mu$ {solid....	.38	< .35	< .38	.38	.38	...	...	.44	...	...	...	.75
liquid... {	.36	< .35	< .38	...	...	...	...	.46	...	...	...	.75
	Zr	Th	Y	Er	Be	Cb	V	Cr	Mo	W	U	
$e\lambda = 0.65\mu$ {solid....	.32	.36	.35	.55	.61	.49	.35	.39	.43	.39	.54	
liquid... {	.30	.40	.35	.38	.61	.40	.32	.39	.40	...	.34	
$e\lambda = 0.55\mu$ {solid....	...	.36	...	...	.61	.61	.29	.53	...	...	.77	
liquid... {	...	...	...	.30	.81	...	...	...	...	...	...
Oxides near freezing-points	NiO	CoO	Fe ₃ O ₄	Mn ₃ O ₄	TiO ₂	ThO ₂	Y ₂ O ₃	BeO	CbO _x	V ₂ O ₃	Cr ₂ O ₃	U ₃ O ₈
$e\lambda = 0.65\mu$ {solid....	.89	.77	.63	...	.52	.57	.61	.37	.71	.69	.60	.30
liquid... {	.68	.63	.53	.47	.51	.69	...	...	...	...	...	.31

For none of the metals examined was there a marked temperature coefficient in the range 900 to 2000° C., and for the most of them this coefficient is negligible, the emissivity usually agreeing also with the value at 20° C. For the white metals the emissivity usually shows very slight or no change at the melting-point, but for gold, silver, copper, and uranium there is a marked discontinuity with red light. For palladium there are anomalies in the behavior of the emissivity at the melting-point; and for platinum the fact that there is a change in emissivity (for $\lambda = 0.65\mu$) on melting would influence the constancy of the Violle standard of light.

STUDIES ON THE SILVER VOLTAMETER.*

By G. A. Hulett and G. W. Vinal.

A COMPARISON has been made of the silver voltameters and methods employed at the Bureau of Standards with the voltameters and methods used at Princeton University. For the details of the previous work at these two institutions reference is made to the *Bureau of Standards Bulletin*, vol. 9, pp. 151, 209, 493; vol. 10, p. 475, and *Transactions of American Electrochemical Society*, vol. 12, p. 257; vol. 22, p. 367. All the experimental data recorded in this paper were obtained in the Laboratory of Physical Chemistry of Princeton University.

A preliminary comparison of the voltameters, using the same electrolyte in all, showed a consistent difference of one part in ten thousand, the Bureau voltameters having the greater deposit. A systematic search for the cause of this difference showed it to be due to two factors: First, the differences in the method of preparing the porous cups; and, second, the differences in the method of washing the deposit.

The Bureau's porous cups were kept in silver nitrate between experiments and produced little change of acidity in the electrolyte of the voltameter, but the Princeton porous cups were usually washed free from the silver nitrate after each experiment and kept in distilled water. It was found in this case that the acidity of the voltameter electrolyte increased. The fact that the Bureau's porous cups were made by a different maker than for the

* Abstract of paper to appear in full in the *Bulletin of the Bureau of Standards*.

Princeton cups was without significance, since when the two different kinds were kept saturated with silver nitrate they produced identical results.

The practice of nearly all observers has been to continue the washing of the deposit until the presence of silver nitrate can no longer be detected in the wash waters by chemical tests, but many have taken the further precaution of allowing distilled water to stand on the deposit for a considerable period of time. As a test on the completeness of the washing, we compared the conductivity of the water before being put in the cup with its conductivity after it had stood in the cup for various periods of time. In every case the conductivity increased with time. It was at first supposed that this increase was due to entrapped silver nitrate gradually soaking out, as we could detect the silver in the water after allowing it to stand over night. All subsequent experiments, for which reference is made to the complete paper, showed that this is not the case, but rather that an electrolytic process was taking place by which the silver was passing into solution at the rate of about 0.006 mg. per hour from a four-gramme deposit of silver on platinum. To confirm this we were able to show by a galvanometer that a current actually passed from the silver through the water to the platinum. In washing the deposits over night this effect becomes appreciable. The work was closed with a final comparison of the voltameters in the light of our experiments, and usually good agreement was found.

Fire-damp Indicator. ANON. (*Sci. Amer.*, cxi, No. 7, III.)—A new fire-damp indicator was recently demonstrated in London. The device is adapted to indicate the presence of fire-damp in coal mines. It is based on the well-known principle of catalytic combustion resulting from placing platinum black in certain explosive (flammable?) gases. The device is in the shape of a torch with two differential thermo-electric couples connected in series with a sensitive galvanometer. Each thermocouple is embedded in a bead of porous material, one of which beads is impregnated with platinum black, so that in the presence of fire-damp it will become heated above the other and generate a thermo-electric current, which will deflect the galvanometer. In order to make the platinum black as sensitive as possible, each bead is heated by a resistance coil to the required temperature. As both of the beads are heated to the same temperature, there is no deflection of the galvanometer under normal conditions.

Action of Colloids on Radio-active Products in Solution.

T. GODLEWSKI. (*Phil. Mag.*, xxvii, 618.)—It has been previously shown that the products of the active deposit of Ra in neutral, alkaline, or weakly acid solutions are in the colloidal state. It was also found that in acidulated solutions or in presence of polyvalent cations the products were deposited at the cathode almost exclusively, while in presence of polyvalent anions the anode is activated on electrolysis. Anomalous results were obtained with RaC, which in pure water solution appears to be deposited partly at the cathode and partly at the anode, although RaA appears at the anode only, and RaB at the cathode. Further experiments appear to explain this. When the atom of RaC arises from the RaB the recoil is only feeble, RaB emitting only a β particle. For this reason, if one of the atoms in the aggregate RaB which forms the centre of a positive hydrosol is transformed into RaC, it will not escape from its environment of RaB atoms, but will be carried with them to the cathode. We may, therefore, expect that only those RaC atoms go to the anode which manage to escape during their transformation, and also those which belong to groups in which the majority of the RaB atoms have already undergone transformation. Detailed experiments have been made on the influence of foreign colloids on the hydrosols of RaA, RaB, and RaC. The results show that the addition of a negative colloid (arsenious sulphide or platinum) in small quantity causes the products deposited at the cathode to diminish in amount and afterwards to disappear. Similarly, positive colloids (ferric oxide) when added in relatively small amount conduce to precipitation of RaA and RaC, which are among negative colloids; in higher concentrations positive colloids absorb them, thus inverting their signs. Radio-active products, as positive hydrosols, can be concentrated by filtration, since these hydrosols are entrained by filter-paper, owing to capillary action.

Durability of Taps for Benzine Tanks. ANON. (*Eng.*, xcvi, No. 2532, 63.)

—Professor Alexander Baumann, of the experimental station for aëronautics and automobilism of the Technical High School at Stuttgart, has made some experiments on the durability of taps, greased and ungreased, when exposed to the flow of benzine. New taps were fitted into two vertical pipes, each three metres high; the upper portions of the pipes consisted of glass tubes, 4 mm. in internal diameter, behind which cardboard scales were fixed. By the aid of mechanism the two taps were opened and closed simultaneously, fifty times in each series, and observations were taken half an hour later of the sinking of the benzine level. The one tap was greased and the other not. The loss of benzine with the greased tap amounted to 5 mm. or less, and did not increase. With the ungreased tap the loss amounted to 145 mm., and rose in later trials to 1500 mm. Nothing is said as to the nature of the grease used; it is merely stated that it should be insoluble in benzine.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, November 18, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 18, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership, 4.

Mr. George R. Henderson, chairman of the Committee on Science and the Arts, introduced Mr. Arthur Atwater Kent, of Rosemont, Pa., and Mr. Elmer A. Sperry, of New York City, who had been recommended to the Board of City Trusts of Philadelphia for the award of the John Scott Legacy Medal and Premium, the former for his Ignition System, and the latter for his Gyro Compass. The Chairman then presented the medals to the recipients.

Dr. Dayton C. Miller, of the Case School of Applied Science, Cleveland, Ohio, was then introduced and presented an interesting communication on "The Photography and Analysis of Sound Waves." He discussed the wave theory of sound, and described, by means of models and lantern slides, the form of the waves of sounds composed of a fundamental tone and overtones. With the aid of lantern photographs, Dr. Miller described the phonodeik, an apparatus for obtaining photographic records of sound waves, and gave the results of experiments made in the Case School in analyzing sounds from the various musical instruments and from the human voice. He outlined the method of analyzing the records obtained with this apparatus by means of Fourier's theorem, and gave some of the mathematical results obtained. At the close of his remarks he showed on the screen impressions received in a projecting phonodeik from the voices of a number of persons in the audience, from a violin, and from a talking machine. In all cases the forms of the waves were clearly seen. The thanks of the meeting were extended to the speaker and to the artists and others who assisted in the demonstration.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
November 4, 1914.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 4, 1914.

MR. GEORGE R. HENDERSON, *Chairman.*

The following report was presented for final action:

No. 2584.—The Humphrey Pump.

Recommendation to award the John Scott Legacy Medal and Premium to Herbert Alfred Humphrey and Alberto Cerasoli, both of London, England, adopted.

R. B. OWENS,
Secretary.

AWARDS OF THE JOHN SCOTT MEDAL.

THE CITY OF PHILADELPHIA, acting on the recommendation of The Franklin Institute, has awarded the John Scott Legacy Medal and Premium to Elmer Ambrose Sperry, of New York, N. Y., for his Gyro Compass. On battle-ships under action the shifting of large masses of magnetic material precludes the use of the magnetic compass, and even on ordinary iron vessels the material of the ship and its disposition must be compensated for. The gyro compass is entirely non-magnetic and is unaffected by the proximity of iron. For some years Mr. Sperry has devoted practically his whole time to overcoming the numerous physical difficulties involved in the adaptation of a gyroscope to a ship's compass in the place of a magnetic needle. He has been able to make an instrument which automatically corrects for the speed and direction of the vessel, and which is unaffected by the rolling of the ship in a heavy sea. His compass may be made in the form of a master compass which may be made to actuate secondary or repeater compasses mounted in any desired part of the vessel. On naval vessels such an arrangement is very desirable, as the master compass may be installed behind heavy armor plate and protected from damage, and may still be available when all the secondary compasses are destroyed.

An award of the John Scott Legacy Medal and Premium has also been made to Arthur Atwater Kent, of Rosemont, Pa., for his Unisparker. The unisparker is an essential element of the Atwater Kent ignition system for automobiles, and consists of a contact-breaker, governor, and distributor, arranged in one structure. The contact-breaker is in the primary of a non-trembler coil circuit, and is so designed as to be operative only when the engine runs in one direction, thus preventing backfiring. The governor automatically advances and retards the spark according to the requirements of the engine. The distributor is in the secondary circuit of the coil and distributes the sparks to the several cylinders. All the parts of the device are especially designed for durability. The contact points are of tungsten and are of large area. The current in the primary circuit can be reversed at will, changing the polarity of the contacts and preventing their disintegration.

AWARD OF THE CERTIFICATE OF MERIT.

MR. W. A. BLONCK, of Chicago, Ill., has been awarded a Certificate of Merit for his Boiler Efficiency Meter. This device consists of two draft gauges, one of which is connected between the atmosphere and the boiler furnace and the other between the furnace and the breeching on the boiler side of the damper. The one gauge, therefore, indicates the resistance of the fire grate and the other that of the combustion chamber and tubes. Sliding indicators are attached to each gauge. To set the meter to give indications of the condition of the boiler to which it is attached, a test of the boiler is run to ascertain the best firing conditions, and the sliding indicators are set to the gauge levels. The fireman then endeavors to maintain these levels whenever the boiler is run. The meaning of deviations from these levels is inscribed on the sliding indicators.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Photographic Society of Philadelphia and of the Sections of Physics and Chemistry and of Photography and Microscopy of The Franklin Institute was held in the Hall of the Institute on Thursday, October 29, 1914, at 8 o'clock P.M., with Dr. Henry Leffmann, president of the latter section, in the chair. The minutes were approved as published.

C. E. Kenneth Mees, Sc. D., Director of the Research Laboratory of the Eastman Kodak Company, Rochester, N. Y., delivered a lecture on "The Physics of the Photographic Process." The effect of exposure and development upon photographic materials was shown to be due to the granular structure of the latter, the light producing an exceedingly small change in each grain. The quantity of energy required to produce this change was considered. It was demonstrated that the properties of the sensitive material depend on the number of changed grains and on the energy expended, and that the sensitiveness and resolving power of the materials bear a direct relation to the size of the grains. A vote of thanks was extended to Dr. Mees, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, November 5, 1914, at 8 o'clock P.M., with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were read and approved.

Maximilian Toch, Ph.D., Director of the Research Laboratory of Toch Brothers, New York, N. Y., delivered a lecture on "Artistic Painting and the Secret of the Old Masters." The various mineral pigments and the one organic color, "madder lake," which were known to the masters of the Dutch and Italian schools from the fourteenth to the seventeenth century, were described, as were the precautions observed by these masters in mixing and applying their paints. The methods of distinguishing a genuine from a spurious painting were outlined. The effects of light and of atmospheric and chemical gases on various pigments were shown by means of experiments and lantern slides. Certain incompatibilities in the mixing of pigments were demonstrated experimentally. After an extensive discussion of the lecture, a vote of thanks was extended to Dr. Toch, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, November 12, 1914, at 8 o'clock P.M., with Mr. George R. Henderson, president of the Section, in the chair.

Mr. George W. Fuller, C.E., Consulting Hydraulic and Sanitary Engineer, New York, N. Y., addressed the meeting on the subject of "Biochemical

and Engineering Aspects of Sanitary Water Supplies." The speaker dealt with the mooted question of the value of measurements of coli bacteria conditions of public water supplies, expressing his opinion that such measurements were almost impossible of correct interpretation. With the aid of lantern slides he illustrated the effect of methods of purification of public water by sedimentation, filtration, storage, etc., upon the death-rate from typhoid fever in the largest American cities. He stated that too much stress should not be laid upon the influence of the public water supply alone upon the public health, but that other factors, such as general sanitation and the carrying of disease germs by the common fly and the mosquito, should be taken into consideration. Mr. Fuller stated that he had embodied his opinions on the biochemical and engineering aspects of the subject of public water supplies in a written communication, which he would refer to the Institute.

WILLIAM E. BULLOCK,
Acting Secretary.

LECTURE ON ARCHITECTURAL ACOUSTICS.

DR. WALLACE C. SABINE, Dean, The Graduate School of Applied Science, Harvard University, Cambridge, Mass., delivered a lecture, entitled "Architectural Acoustics," in the Hall of the Institute on Friday evening, November 6. Dr. Sabine gave the results of his investigations, extending over a period of some eighteen years, to determine the absorbing power of the various materials which enter into the construction and furnishing of an auditorium. He spoke of how, in the early stages of his work, these investigations were confined to the determination of the coefficient of absorption for sound having the pitch of violin C, but how they were later extended from a range of pitch from three octaves below to three above violin C. He described how other aspects of the acoustic problem, such as interference, resonance, and echo, presented themselves and were taken up in his work simultaneously. Dr. Sabine called attention to the incompleteness of his measurements on account of the vast amount of labor involved in obtaining them, and suggested the further extension of this work by architects as opportunities presented themselves.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, November 11, 1914.)

RESIDENT.

DR. GEORGE S. CRAMPTON, 1700 Walnut Street, Philadelphia, Pa.
MR. JOHN J. KOHLER, 4121 North Sixth Street, Philadelphia, Pa.
MR. GEORGE F. SCHAEFER, 16 North Sixty-first Street, Philadelphia, Pa.

NON-RESIDENT.

MR. GEORGE T. CLARKE, Leland Stanford Junior University, Stanford University, Cal.

CHANGES OF ADDRESS.

- MR. M. J. CAPLES, 50 East Broad Street, Columbus, Ohio.
MR. SAMUEL S. FELS, Thirty-ninth and Walnut Streets, Philadelphia, Pa.
MR. L. J. R. HOLST, 5406 Baltimore Avenue, Philadelphia, Pa.
MR. EDWARD A. STROUD, Strafford, Pa.
MR. ERNEST STUTZ, 87 Nassau Street, New York, N. Y.
MR. SIMEON TRENNER, 817 Crescent Place, Chicago, Ill.
MR. F. R. WADLEIGH, 426 Real Estate Trust Building, Philadelphia, Pa.
DR. WILLIAM J. WILLIAMS, 1305 Foulkrod Street, Frankford, Pa.
-

NECROLOGY.

Dr. William Lefland Dudley was born at Covington, Ky., in 1859. He was educated in the common schools of his native town and at the University of Cincinnati, from which he was graduated Bachelor of Science in 1880. He continued his studies at the Miami Medical College, and received his degree of Doctor of Medicine in 1885. From 1879 to 1886 he was a professor of chemistry in the Miami College. In 1895 he was made Dean of the Medical Department of Vanderbilt University, and he occupied that position until two years ago, when he was compelled by failing health to resign. He was the discoverer of the physiological properties of X-rays and of the luminosity of comets, and was the author of valuable papers on chemical subjects. He was a director of the Tennessee Centennial Exposition in 1897 and a member of the Executive Committee of the Eighth International Congress of Applied Chemistry in 1912 and vice-president of the Section on Law as Affecting Chemical Industry. He was a prominent member of the American Chemical Society and the American Association for the Advancement of Science. He was elected to membership in the Institute in 1913.

LIBRARY NOTES.

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THOMSON, SIR J. J.—The Atomic Theory. Romanes Lectures. 1914.
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- Atchison, Topeka & Santa Fe Railway Company, Nineteenth Annual Report. New York, 1914. (From the Company and Robert D. Jenks, Esq.)
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The Most Important Question of the Age: Is the Efficiency of a Thermodynamic Reversible Cycle Independent of the Working Medium? by Jacob T. Wainwright. 8 pages, 8vo. Chicago, 1914.

Stresses Due to Shrinkage of Ferro-concrete. **CONSIDÈRE.** (*Comptes Rendus*, clviii, 1096.)—This criticises the views of Rabut, who holds that the values of shrinkage-stresses given by the *Commission officielle du Ciment Armé* are excessive. Mortars and concretes dilate in water and contract in air. O. Graf's results are quoted and compared with recent experiments at the *Ecole des Ponts et Chaussées*, which show that after 54 months' immersion the shrinkage decreased from 0.370 mm. to 0.130 mm. On exposure to air the shrinkage increased from 0.130 mm. to 0.430 mm. in 35 months, and at such a rate as to corroborate the shrinkage given by Graf as 0.512 in six years. Alternating stresses in concrete have the same effects as in metals, but the stresses due to shrinkage and dilatation do not vary rapidly or much in comparison with those due to temperature and live loads. The author doubts if the matter is susceptible of analysis, and recommends direct-experiments on stresses in actual constructions.

CURRENT TOPICS

Synthesis of Ammonia by Means of Aluminum Nitride.

C. MATIGNON. (*Chem. Zeit.*, xxxviii, 894.)—Serpek has shown that when a current of nitrogen is passed through a mixture of alumina and carbon at 1800° C. the alumina is rapidly converted into aluminum nitride:



The heats of formation of the nitrides of the following metals, calculated on N_2 , are: Mg, 119.7; Ca, 111.2; Si, 90; Al, 110 cal. Aluminum combines directly with atmospheric nitrogen when introduced at a high temperature into a flask containing nitrogen, or if a mixture of aluminum powder and carbon is strongly heated and a current of nitrogen introduced through a carbon tube within the mass. A temperature of 2000° C. is easily obtained in this way. Serpek's process can be accelerated, and effected at 1500° C. by the aid of the catalytic action of hydrogen and iron. In experiments at 1500° C., lasting one hour, in the presence of hydrogen, the product contained 12.85 per cent. N; in the presence of iron, 7.7 per cent., and in the presence of both hydrogen and iron, 27.07 per cent. Bauxite containing iron oxide can therefore be used for the process, and subsequent decomposition of the nitride yields ammonia and pure alumina. The nitride is heated under pressure with a solution of sodium aluminate of 20° to 21° Be. (sp. gr. 1.162 to 1.171), and the alumina is then precipitated by adding some precipitated alumina, the solution being used again without further concentration. The cost of preparing alumina from the nitride in this way is about half that of preparing it from bauxite by heating under pressure with caustic soda and sodium aluminate of 40° Be. (sp. gr. 1.383). When the process is worked solely for the production of ammonia, the alumina is not purified, and the decomposition of the nitride is simpler. A furnace for the manufacture of aluminum nitride by Serpek's process comprises a fixed chamber arranged between two inclined rotating cylindrical chambers which open into it. The lower of these rotating chambers contains a resistance and forms an electric furnace; the lining is of aluminum nitride. Bauxite is fed into the upper end of the rotating chamber and passes downward through the chambers, mixing with carbon which is fed into the fixed chamber, and meeting a current of nitrogen which is admitted at the lower end of the electric furnace. The carbon monoxide formed in the reaction is burned at the lower end of the upper chamber, and serves to preheat the bauxite. Each of the rotating chambers is 25m. long and a current of 10,000 ampères at 230 volts is used.

Quantity and Character of Creosote in Well-preserved Timbers. G. ALLEMAN. (*Proc. Amer. Wood Preservers' Assoc.*, 88.)—The creosote oils extracted from timber which had been in use many years showed an average of 32.9 per cent. distillate below 270° C. and 66.8 per cent. oils of high boiling-point. The defects of most modern creosote preservatives are deficiency in basic oils of high boiling-point and the substitution for these of tar or other viscous substances. Under proper conditions of distillation a stable, heavy creosote oil (sp. gr. 1.10) could be manufactured from coal tar, containing nothing which boils below 210° C., for general purposes not more than 50 per cent. of the total should distil below 315° C., and for wood-paving blocks not more than 35 per cent. The qualities demanded are penetrating power, stability, and preservative and water-proofing value. All these are possessed in a high degree by pure, heavy, creosote oil. Tar has a very low penetrating power, even when injected at a high temperature, and wood treated with a mixture shows a separation of the components (oil, tar, and carbon) at the margins of the close-grain rings. As regards stability, losses occur owing to volatilization, extraction by water, and crystallization in wood impregnated with light creosote oils. Preservative value may depend upon direct antiseptic action or permanent adhesion of a stable oil-coating to the walls of the minutest cells; external filming without penetration is of little account. In the light oils the antiseptic constituents predominate, but are volatile and largely soluble in water. The heavy oils are sufficiently rich in the higher homologues of cresols, both these and the protective oils being far more stable. Water-proofing depends on the complete coating of the cell walls with an oily deposit which excludes moisture.

Surface Film on Polished Metals. G. T. BEILBY. (*Roy. Soc. Proc.*, Ser. A, 89, 593.)—Shows that the minute pits in a polished surface of copper are covered by a transparent or highly translucent film which crosses the empty pit without any support from below. By suitable methods of polishing, the skin developed on the surface may be raised to a maximum thickness or reduced to a minimum. Photomicrographs in natural colors accompany the paper, and show the bluish film crossing the pits, and the empty pits after the film has been dissolved by a 10 per cent. solution of ammonium persulphate acting for twenty or thirty seconds. The thickness of the film is probably of the order of 10 to 20 μ .

Recent Developments of the Hydraulic Reaction Turbine. H. B. TAYLOR. (*Gen. Electr. Rev.*, xvii, 533.)—Treats under the following captions: Design and testing of a turbine; Mechanical features of turbine construction; General arrangement of unit; Volute casing; Draught tubes; Supporting rings and face plates; Pressure thrust bearing; Roller bearing; Mechanical details; and Speed regulation.

Causes of Discoloration of Organic Fibres (e.g., Bleached Cotton). B. HAAS. (*Papierfab.*, xii, 891.)—The tendency of bleached cellulose to discoloration was studied with samples of pure cotton cloth: (a) American, (b) Egyptian. A most useful test consisted in boiling the fabric with distilled water, draining, and exposing to light; in many cases the discoloration was already apparent in the aqueous extract. Fabrics bleached with bleaching powder solution showed the greatest tendency to discoloration; those bleached by electrolytic liquor were better, and those bleached with sodium peroxide were almost stable in color. Another test consisted in damping the cellulose and subjecting it in small heaps to a retting process with a thermometer embedded in the heap; lack of purity and tendency to discoloration were then indicated by a greater or less rise of temperature. Unbleached cottons responded to this test in the highest degree, but the bleached fabrics also followed in the order of bleaching processes mentioned above. In all cases the Egyptian samples showed more distinct reactions than the corresponding American samples. The inferior results obtained with bleaching powder liquor are attributed partly to the deleterious action of the calcium chloride and free lime, and partly to the fixation of alkaline earth compounds on the fibre in an insoluble condition; moreover, the benefit to be derived from the use of soft water in the bleaching process is forfeited. In the electrolytic bleach the sodium chloride and chlorate may have a minor deleterious action, but the fixation of insoluble calcium compounds is avoided. Discoloration is due to the presence of impurities of original or secondary nature, mechanically or chemically combined with the true cellulose, and to the auto-oxidation or alteration of these impurities. The nearer the cellulose to complete purity the more stable is the bleached color.

Cooling of Spheres. F. VERCELLI. (*N. Cimento*, vi, Ser. 6, 427.)—Two spheres of different substances but equal radius, cooled from the same initial temperature until they attain a given final temperature at the centre, have coefficients of thermal conductivity which are directly proportional to the density and specific heat, and inversely proportional to the time required for cooling. There is described a method governed by rigorous formulæ and involving the use of elliptic functions.

Platinum Discovered in Germany. ANON. (*Sci. Amer.*, cxi, No. 7, III.)—Electrical engineers will be interested to learn that extensive deposits of platinum have been discovered at Wenden, in Westphalia, and that they are soon to be worked on a large scale. Hitherto we have had to depend almost entirely upon the mines in the Ural Mountains for this metal which is so indispensable in electrical apparatus. Fully 95 per cent. of the world's production of platinum has come from Russia.

Manufacture of Galalith. G. BONWITT. (*Z. Angew. Chem.*, xxvii, 2.)—Galalith is prepared from a specially pure casein, from sweet milk perfectly freed from fat by centrifuging; the casein is precipitated by rennet, since acids make it quite unsuitable. The curd is drained and dried, forming lumps 8 to 12 mm. thick. These are ground, first in a fluted-roller mill, then in a porcelain-roller mill, to a gritty meal. The meal is moistened with a given quantity of water, and must then be worked up within twelve hours, otherwise it begins to ferment. The moist meal, colored as required, is worked up between steel helices to a plastic mass, which is then hot-pressed in hydraulic presses. The pressed cake is hardened in a solution of formaldehyde of accurately adjusted concentration, which is circulated continuously to avoid the formation of paraformaldehyde. The length of treatment varies from two to thirty weeks, according to the thickness of the articles; the rooms are heated and well ventilated. Drying is effected in a current of warm air. The hardening takes away the extreme brittleness of the casein and imparts the qualities of natural horn. Galalith is a good electrical insulator; a plate 2 mm. thick will resist 16,000 volts. The specific gravity is 1.317 to 1.35 (celluloid, 1.34 to 1.40). The hardness is 2.5 (celluloid, 2). It resists oily liquids and acids, but is swelled by alkaline liquids. Its chief drawback is its hygroscopicity; it absorbs 30 per cent. of its weight of water in twelve days. It is not elastic like celluloid, and breaks when slightly bent. On account of its tendency to flake it cannot be worked as well as celluloid, and sheets cannot be prepared less than 2 mm. thick. It is chiefly used in the turning trade and for the manufacture of buttons, combs, and piano-keys; it does not turn yellow.

Three-phase Towing Locomotives for the Panama Canal. ANON. (*Electr. Rly. Journ.*, xliii, 835.)—Forty locomotives have been built by the General Electric Company, with tractive power up to 47,500 pounds. Four of these, two on each side, will propel steamships through the locks. No vessel is allowed to go through the locks under her own power. The locomotive is propelled by a rack rail while towing at a speed of two miles per hour; when running idle the rack pinion is released and the speed increased to five miles per hour. The locomotive is driven by two 75-horse-power motors; in the centre there is a vertical windlass with drum, the capacity of which is 800 feet of one-inch steel hawser cable.

Recent Advances in the Manufacture and Use of Fertilizers. A. STUTZER. (*Chem. Zeit.*, xxxviii, 310.)—Potassium salts have recently been used for the top dressing of cereals, and are better adapted than kainit for this purpose. Artificial nitrogen compounds from atmospheric nitrogen—nitrolim, calcium nitrate, ammonia, nitric acid, and urea—are being increasingly used in Germany.

Notes on Sulphite Pulp Manufacture. A. FROHBERG. (*Chem. Zeit.*, xxxviii, 126.)—The idea that the system of digesting with indirect steam is superior to the direct steam system is not correct. When boiling with live steam the circulation is much better and the mixing of the "acid" and rise of temperature are more rapid: Below 100° C. adsorption phenomena occur, the colloidal wood adsorbing sulphurous acid from the liquor; consequently high concentration and maximum surface development are favorable. The chief objection to the direct steam system is the necessity for blowing over large quantities of liquor, owing to the dilution. Thus liquors driven over and regenerated contain organic matters which weaken the efficiency of the "acid" by promoting the decomposition of the sulphurous acid into trithionic acid. It is better to separate the gases from the liquors blown over and utilize them separately. The organic matters in the "acid" may be determined colorimetrically after driving off the sulphurous acid, or oxidizing by hydrogen peroxide. Acid produced in the towers at 3 to 3.2 per cent. strength can be enriched up to 4.5 per cent. by a systematic regeneration process. Blowing over also causes loss of heat; the necessity for blowing over increases with steam of low heat capacity; the use of superheated steam up to 220° C. affords considerable economy in this direction. Good distribution of superheated steam is essential; a maximum digestion temperature of 145° C. does not injure the quality of the cellulose. The formation of sulphur trioxide is at a maximum at 400° to 500° C.; at 900° to 1000° C. the sulphur trioxide is decomposed again into sulphur dioxide and oxygen. The furnace must, therefore, be worked as hot as possible in order to obtain gases rich in sulphur dioxide; the gases must be immediately cooled by direct spraying with water to reduce the temperature to 90° to 100° C.

Mercury-vapor Lamp for Inspecting Translucent Products. ANON. (*Electr. World*, lxiv, No. 2, 78.)—Cube sugar and ivory piano keys are inspected under artificial illumination produced by mercury-vapor lamps with greater speed and accuracy than can be attained in ordinary daylight. Raw sugar is a brown substance, while the refined product is pure white, its whiteness being due to the same cause as the whiteness of snow, since both consist of small transparent crystals. Any impurity in sugar is manifested by changing the white to a shade of yellow. To detect impurities, plates of the crystallized sugar one inch thick are examined by looking through them toward a mercury-vapor lamp. When thus viewed the yellow impurities stand out clearly in this bluish-green light. The color of ivory varies from the outside to the centre of the tusk to such an extent that manufacturers sort the pieces into sixteen different shades. Formerly this sorting could be done only in bright daylight, but with the light of the mercury-vapor lamp grading can be done without limitation at any hour of the twenty-four.

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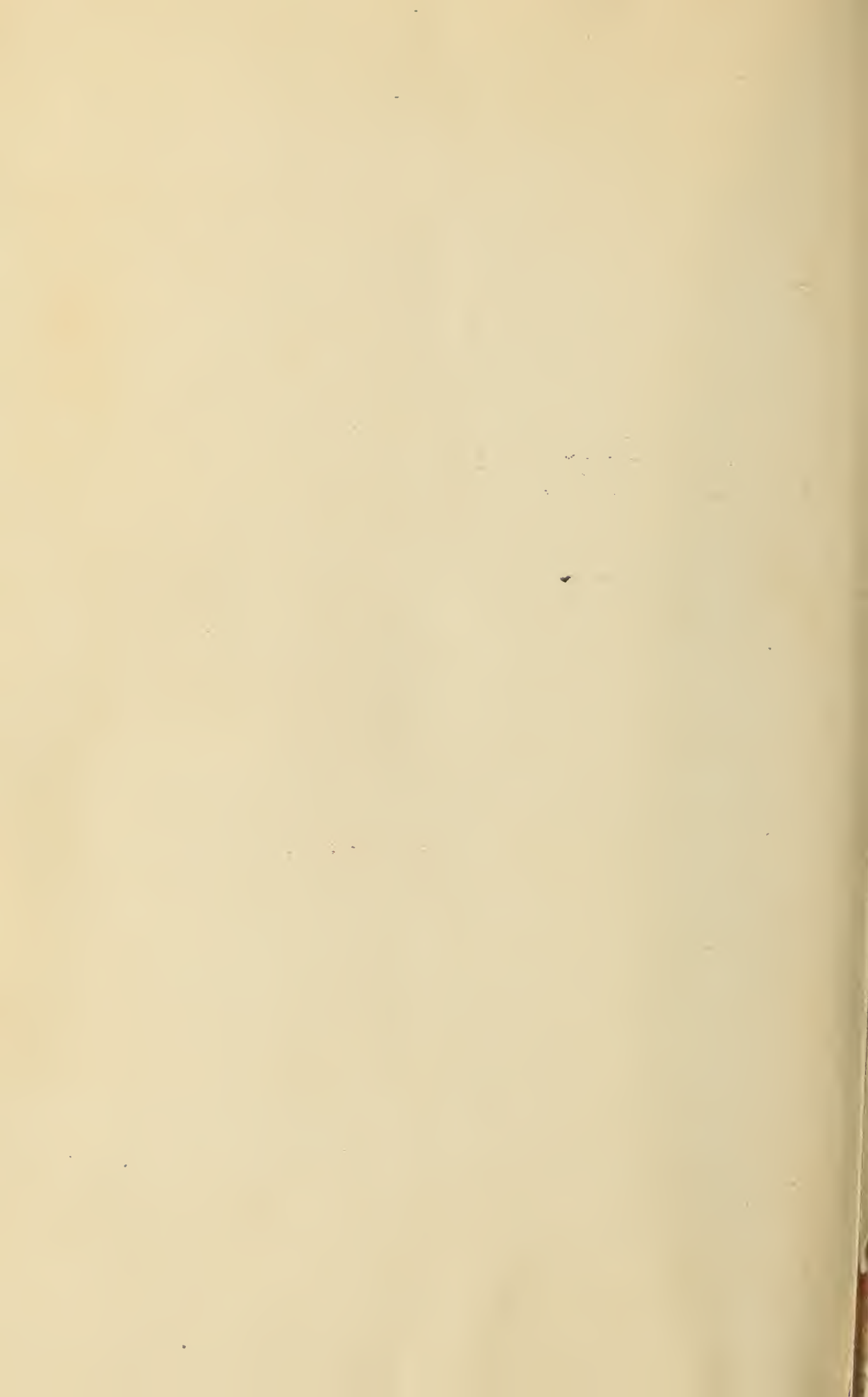
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